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BIOENERGY RESEARCH AND DEVELOPMENT

BIOMASS
BIOMASSE

A SUMMARY OF THE FEDERAL PROGRAM
APRIL 1983 TO MARCH 1984

DIVISION OF ENERGY

OTTAWA

NRCC 24144

Canada

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BIOENERGY RESEARCH AND DEVELOPMENT

A Summary of the Federal Program
From
April 1983 to March 1984

Compiled and Edited by

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of the

Bioenergy Program

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THE BIOENERGY RESEARCH AND DEVELOPMENT PROGRAM 1983-1984

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Forestry - Logging Residue

Forestry - Biomass Factors

Forestry - Energy Plantations - Productivity

Agriculture - Animal Residues Biomass Factors

Agriculture - Plant Residues

Agriculture - Energy Crops

Peat

Algae

PROJECT DATA SHEET # 454

TITLE	Identification of Logging Waste in the Vancouver Forest Region	**PROGRAM IDENTIFICATION**	4.3.1.2 Biomass Resource Assessment/ Forestry - Logging Residue
		DURATION	January 1984 - March 1984
CONTRACT #	KH603-3-1212(PSB83-00566) P-296	**COST**	$4,438
CONTRACTOR	Nawitka Renewable Resource Consultants Ltd. 836-840 Cormorant Street Victoria, British Columbia V8W 1R1	**SPONSOR**	Environment Canada
		SCIENTIFIC AUTHORITY	G.H. Manning Pacific Forest Research Centre Canadian Forest Service 506 West Burnside Road Victoria, British Columbia V8Z 1M5 Tele.: (604) 388-3811

OBJECTIVE

1. a) Identify logging waste by species or species groups
   b) identify logging waste left as slash or at heigh lead or grapple landings
   c) test or identify if accumulation varies by
      i) season logged
      ii) gentle as opposed to steep slopes
   d) identify logging waste by type of piece (i.e. log, tree top, stump, etc.)
2. Objectives in (1) obove are largely qualitative and can be analyzed on the basis of piece counts. Basic or significant relationships, however, should be further quantified by volume or if possible weight:
   a) where appropriate report significant relationships on a volume basis
   b) where appropriate and where conversion factors are available report significant relationships on a weight basis (i.e. green tonnes)

DESCRIPTION

The data are computerized, but not available in program form. Our access is limited to a computer printout of sample plots taken in the "waste" management program of the Ministry of Forests. These plots are the basis for further analyses for internal management purposes by the Vancouver Forest Region.
The plot information covers the five Timber Supply Areas and six of the T.F.L's in the Vancouver Forest Region. Essentially, the plot information relates to wood residual to logging, and gives an estimate of type or piece of waste, a variety of measurements and the volume. The available sample covers approximately 700 plots identifying some 6000 - 8000 pieces where logging occurred in 1981 and the year of record (sampling) was 1982.
The following information is available that relates to plots and pieces:
Plot information:
1. Location of sample area
   - timber supply area
   - licence, block, etc.
2. Size of logged area sampled
   - gross and net hectares
   - area of slash sampled
   - area of high lead landings sampled
   - area of grapple or roadside sampled
   - plot areas taken
3. Topography of area sampled
   - type of terrain (even, rolling, gullied, broken)
   - percent slope (5% intervals)
4. Season logged (spring, summer, fall, winter)

Piece information:
1. Piece listings (lines of information, one per piece) by type of plot (slash, high lead, or grapple)
   - each listing referenced to above plot information.

CONTINUED

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$4,438			$4,438

REPORTS

Nawitka Renewable Resource Consultants, "Identification of Logging Waste in the Vancouver Forest Region," Victoria, British Columbia, 1984. ENFOR project P-296. Final report.

STATUS AND COMMENT

Contract completed

84/12/06

PROJECT DATA SHEET # 213

TITLE	Determination of Biomass and Nutrient Content in Trees, Ground Vegetation and Soil of Aspen Stands in Alberta
CONTRACT #	KL015-1-0012 (0SS81-00114) P-205
CONTRACTOR	Alan Moss & Associates Ltd. 1334 St. Paul Street Kelowna, B.C. V1Y 2E1
PROGRAM IDENTIFICATION	4.3.1.3 Biomass Resource Assessment/ Forestry-Biomass Factors
DURATION	August 1981 - March 1984
COST	$422,711
SPONSOR	Environment Canada
SCIENTIFIC AUTHORITY	L.G. Brace Northern Forest Research Centre Canadian Forestry Service 5320-122 Street Edmonton, Alberta T6H 3S5 Tel.: 435-7210
TECHNICAL LIAISON OFFICER	I.K. Edwards Northern Forest Research Centre Edmonton, Alberta T6H 3S5

OBJECTIVE

The major objective of this project is to determine biomass and nutrient content of trees, understory vegetation, forest floor and mineral soil within aspen stands of the mixedwood region. These data (along with tree data being collected) will be necessary to assess fully the effect of whole tree removal on the nutrient budget within this type of forest ecosystem. The latter information will be useful in assessing the availability of soil nutrients for the succeeding tree crop

DESCRIPTION

Field work will consist of identification and sampling description of representative aspen stands of fire origin in Alberta. There will be 36 plots, 12 for each of 3 age classes, ranging from 15 to 45 years, on a medium site.

There will be 5 tree samples per plot to cover the diameter range by 5 groupings. This will give a total sample of 180 aspen trees. Each stand sampled will be at least 95% hardwood, primarily aspen, and confined to a single clone.

Field sampling must be restricted to the time period July 15 to September 15 to minimize fluctuations in nutrient concentration of tree components in the sample.

Tree sampling will follow the procedure used in ENFOR Project P-92, with the addition of root information. Components sampled will therefore be stump, roots, merchantable and non-merchantable stem, branches, and foliage. Ground vegetation will be sampled also. Wood, branches, roots, foliage and ground vegetation will be analyzed for N, P, K, Ca, Mg and S.

At each plot, samples of the forest floor and each of 3 horizons of mineral soil will be sampled. These will be analyzed for pH, electrical conductivity, texture, bulk density, organic matter, N, P, K, Ca, Mg, S, and available water capacity. This data will be used to determine biomass and nutrient content on an area basis.

Data sufficient to compute stem wood volume & crown & root mass for each tree sample, following ENFOR P-92 procedures, will be taken. Forms for these data will be supplied.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR	IN-HOUSE	CUMULATIVE TOTAL
1981-82	$ 41,827			$ 41,827
1982-83	$301,386		$ 17,000	$360,213
1983-84	$ 57,498		$ 5,000	$422,711

REPORTS

Final draft report due August 31, 1983.

CONTINUED

STATUS AND COMMENT

Laboratory analysis on schedule. Vegetation analysis complete. Soils completed by April 1983.
84-12-07

PROJECT DATA SHEET # 225

TITLE Coordination of ENFOR Biomass Estimation Projects, and Development of Biomass Estimates based on Provincial Timber Inventories

CONTRACT # KL229-1-4260 (OSS81-00092)
P-227, P-266

CONTRACTOR
T.M. Thomson & Associates Ltd.
1006 Government Street
Victoria, B.C.
V8W 1X7

PRINCIPAL INVESTIGATOR W.A. Hopwood

PROGRAM IDENTIFICATION 4.3.1.3
Biomass Resource Assessment/
Forestry-Biomass Factors

DURATION July 1981 - March 1984

COST $223,777

SPONSOR Environment Canada

SCIENTIFIC AUTHORITY
M.R. Keen
Forest Statistics and
Systems Branch
Environment Canada
Chalk River, Ontario
KOJ 1JO

OBJECTIVE

To coordinate the development of biomass estimation equations, and their application on the forest inventory data of all provinces in order to generate forest biomass estimates according to specifications of the Canadian Forest Resource Data System.

DESCRIPTION

1. Review biomass estimation project proposals and make recommendations for support.
2. Coordinate biomass estimation projects within the CFS by maintaining liaison with regional establishments, and by monitoring progress in developing and testing procedures to convert timber inventories to biomass estimates.
3. Develop minimum criteria for biomass inventories and methods for inventory conversion to mass estimates.
4. Plan and facilitate biomass pilot projects with the Canadian Forest Resource Data System.
5. Establish national and regional data bases for the storage of biomass data gathered on ENFOR projects.
6. Prepare comprehensive reports on work accomplished, and document field and office (software) procedures.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1981-82	$ 84,000			$ 84,000
1982-83	$ 99,777			$183,777
1983-84	$ 40,000			$223,777

REPORTS

STATUS AND COMMENT

For previous work refer to project data sheet 208 (P-219)

84/12/07

PROJECT DATA SHEET #	296
TITLE	Stem Measurement and Mass Data Collection for 15 Native Hardwood Species in Ontario
CONTRACT #	KH415-2-0029 (OSS82-00038) P-234
CONTRACTOR	Dendron Resource Surveys Ltd. P.O. Box 6493 Postal Station 'J' Ottawa, Ontario K2A 3Y6
PRINCIPAL INVESTIGATOR	U. Nielsen

PROGRAM IDENTIFICATION	4.3.1.3 Biomass Resource Assessment/ Forestry - Biomass Factors
DURATION	June 1982 - March 1984
COST	$186,275
SPONSOR	Environment Canada
SCIENTIFIC AUTHORITY	I.S. Alemdag Petawawa National Forestry Institute Canadian Forestry Service Environment Canada Chalk River, Ontario K0J 1J0 Tel.: (613) 589-2880

OBJECTIVE

To collect and process biomass data on hardwood species in Ontario in order to develop biomass equations and establish biomass/volume relationships.

DESCRIPTION

The contract will include felling and measuring 1140 sample trees in the field, and processing sample material at the laboratory. The sample trees will be taken in pure or mixed and not severely disturbed (fire, insect, diseases, logged) stands of the species to be studied. These trees will be of at least average health and vigor, and with unbroken tops and undeformed stems. The sample trees will cover the range of diameter at breast height outside bark (dbhob) of each of these species, starting from 0.1 cm. While selecting the sample trees, particular attention will be paid to including the full range of the height (h) distribution in each of the diameter classes. In addition to these sample trees, 10-15 seedlings under 1.30 m height from each species, will be taken. Also, some dead trees will be sampled from all species including various tree sizes.

FUNDING

FISCAL YEAR	SPONSOR	in-house		CUMULATIVE TOTAL
1982-83 1983-84	$120,000 $ 64,275	$ 2,000		$122,000 $186,275

REPORTS

STATUS AND COMMENT

Collection of the data on the fifteen tree species was completed in 1982 and 1983, and the contract terminated.

I.S.A.

84/12/06

PROJECT DATA SHEET #	423	**PROGRAM IDENTIFICATION**	4.3.1.3 Biomass Resource Assessment/ Forestry-Logging Residue
TITLE	Determination of the Supply and Demand for Residential Fuelwood on Southern Vancouver Island and the Lower Mainland	**DURATION**	July 1983 - December 1983
		COST	$30,000
CONTRACT #	KH603-3-0025(OSB83-00247 P-252	**SPONSOR**	Environment Canada
CONTRACTOR	T.M. Thomson & Associates Ltd. 1006 Government Street Victoria, B.C. V8W 1X7	**SCIENTIFIC AUTHORITY**	G.H. Manning Pacific Forest Research Centre Canadian Forest Service 506 West Burnside Road Victoria, British Columbia V8Z 1M5 Tele.: (604) 388-3811

OBJECTIVE

DESCRIPTION

To satisfy the objectives of this project we propose to conduct the following studies:

- Survey of fuelwood resources
- Survey of fuelwood industry
- Survey of public (consumer)
- Literature review

Factors affecting availability of fuelwood will be identified and supply and demand projections for various scenarios will be prepared. In addition, special problems created by increased fuelwood demand will be discussed in the course of the survey and potential solutions or recommendations will be developed.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$30,000			$30,000

REPORTS

T.M. Thomson & Associates Ltd., "Residential Fuelwood Supply and Demand in Greater Victoria And Vancouver," Victoria, B.C., March 1984, ENFOR Project P-252.

STATUS AND COMMENT

Completed March 31, 1984

84/12/06

PROJECT DATA SHEET # 425

TITLE
Determination of Green and Dry Volume Wood Densities of Prairie Provinces/NWT Inventory Tree Species

CONTRACT #
KH505-3-0035(0SG83-00050)
P-255

CONTRACTOR
University of Alberta
Edmonton, Alberta
T6G 2J9

PRINCIPAL INVESTIGATOR
M.M. Micko

PROGRAM IDENTIFICATION
4.3.1.3
Biomass Resource Assessment/
Forestry-Biomass Factors

DURATION
July 1983 - February 1984

COST
$26,000

SPONSOR
Environment Canada

SCIENTIFIC AUTHORITY
T. Singh
Environment Canada
Northern Forest Research Centre
5320-122 Street
Edmonton, Alberta
T6H 3S5
Tele.: (403) 420-4063

OBJECTIVE

DESCRIPTION

Field data and increment core of disk samples are being collected in the prairie provinces and N.W.T. to determine green and dry volume wood densities. Tree species include:
Softwoods: Jack pine, lodgepole pine, red pine, scots pine, black spruce, white spruce, alpine fir, balsam fir, tamarack larch, and douglas-fir.
Hardwood: Trembling aspen, white birch, balsam poplar, manitoba maple, ash (black, green), alder, white elm, bur oak, eastern white cedar, willow, basswood, dwarf birch, eastern white pine, showy mountain ash, hop-hornbeam, hackberry, and wild plum.
As the exact number of total samples obtained will not be know till the end of summer 1983 (see appendix B), the contractor should admit quotations on per hundred sample basis separately for each of work required to be done. At the minimum there will be 2000 samples for wood density and 1 - 3 per core/disk.

(a) Prepare samples for laboratory analysis and determine wood density for each on green and ovendry volume basis according to accepted scientific standards.
(b) Determine statistical characteristics of wood density; these include mean, standard deviation, maximum, minimum, coefficient of variation, standard error--computed for each species and diameter class separately and collectively.
(c) Analysis of variance to test for variation in the green-volume and dry-volume wood densities according to following sources of variation:
    1) Tree species, diameter class, and their interaction.
    2) Tree species, province/territory, and their interaction.

These analyses should provide summary statistics on the above mentioned variates, in addition to standard information required for analysis of variance.

(d) Prepare juvenile, middle age and mature wood samples for laboratory determination of wood densities for the higher diameter classes (Ô20 cm diameter outside bark) and provide raw data on these characteristics.
(e) Prepare a report on all the results obtained.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$26,000			$26,000

REPORTS

CONTINUED

STATUS AND COMMENT

PROJECT DATA SHEET # 427

TITLE Oven-Dry Mass and Volume Equations for Canadian Wood Species

CONTRACT # KH415-3-0086(OSS83-00042)
P-258

CONTRACTOR Linda R. Roy
R.R. 6
Pembroke, Ontario
K8A 6W7

PROGRAM IDENTIFICATION 4.3.1.3
Biomass Resource Assessment/
Forestry-Biomass Factors

DURATION June 1983 - March 1985

COST $36,000

SPONSOR Environment Canada

SCIENTIFIC AUTHORITY I.S. Alemdag
F. Evert
Petawawa National Forestry Institute
Candian Forestry Service
Department of the Env.
Chalk River, Ontario
K0J 1J0
Tele.: (613) 598-2880

OBJECTIVE

DESCRIPTION

1. Following consultation with the Scientific Authority submits a plan for a storage and retrieval system for source data (detailed measurements on about 12,000 trees that will be available from the Forestry Statistics and Systems Branch (FSSB) in early Summer of 1983). After approval, sets up the appropriate storage and retrieval system and writes a report on it.
2. Under the direction of the Scientific Authority, develops computer programs and utilizes computer systems, with the objective of integrating by tree species, data sets collected from various geographic regions of Canada, into the following:
(a) Standard or two-entry (height and dbh) national oven-dry mass and volume equations that will fit into compatible systems for estimating the standing volume and oven-dry mass of both individual trees and stands, and for forecasting both tree and stand growth and yield;
(b) Estimates of basic density of wood by tree species that are compatible with estimates of oven-dry mass and volume;
(c) Estimates of component proportions of the above-ground part of trees, in terms of oven-dry mass, for the purpose of, for example, converting existing yield tables showing the volume of the main stem, to the oven-dry mass of the above-ground part of trees;
(d) Under the direction of the Scientific Authority, performs other related duties.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1983-84 1984-85	$14,850 $21,150			$14,850 $36,000

REPORTS

STATUS AND COMMENT

The data sheets are accurate for the period April 1983 to March 1984. The study was scheduled to be completed in two years. Therefore, a new contract was prepared, for the amount of $ 21,150. The Scientific Authority for the new contract is F. Evert.

84/11/29

PROJECT DATA SHEET # 428

TITLE Field Sampling to Establish a Data Base for Biomass Growth and Yield Equations

CONTRACT # KH208-3-0062(DSC83-00233)
P-262

CONTRACTOR
Woodlot Service (1978) Ltd.
320 Maple Street
Frederiction, New Brunswick
E3A 3R4

PROGRAM IDENTIFICATION 4.3.1.3
Biomass Resource Assessment/
Forestry-Biomass Factors

DURATION July 1983 - March 1985

COST $292,030

SPONSOR Environment Canada

SCIENTIFIC AUTHORITY
M.F. Ker
Environment Canada
P.O. Box 4000
Fredericton, New Brunswick
E3B 5P7
Tele.: (506) 452-3512

OBJECTIVE

To obtain field measurements from 700 temporary sample plots through the Maritimes, to be used by CFS to establish a data base of stand biomass and stand age information.

DESCRIPTION

1) Install 700 0.04-ha temporary sample plots in natural stands throughout New Brunswick and Nova Scotia, covering the full range of ages from 10 years to 100+ years. Stands sampled should be in undisturbed, natural condition with no evidence of harvesting and no severe defoliation. About 40% of the plots should be in Nova Scotia, 60% in New Brunswick. The allocation of plots among the three major cover types (softwood, mixedwood, hardwood) should be roughly proportional to the relative areas of each cover-type within each province. A map showing approximate plot locations will be provided to the contractor.
2) On each plot all live trees above 9.0 cm DBH will be tallied by 2-cm diameter classes and species. Trees between 1.0 and 9.0 cm DBH will be tallied on a concentric sub-plot of 0.01 ha by species and 2-cm DBH classes.
3) Measurement of total height, DBHOB, total age at 1.3 m above ground, and age from release at 1.3 m above ground on five dominant and codominant trees on each plot. This data will be used by the Canadian Forestry Service to estimate stand age and site index for each plot.
4) Measurement of total height and DBH on a randomly selected sub-sample of five trees per plot. This data will be used by CFS to develop height-diameter curves for estimating heights of remaining trees.
You will also be required to attend a 1-2 day workshop in Ottawa during each of the two years of this contract to discuss results of work carried out.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1983-84 1984-85	$181,265 $110,765			$181,265 $292,030

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 429		**PROGRAM IDENTIFICATION**	4.3.1.3 Biomass Resource Assessment/ Forestry-Biomass Factors
TITLE	Study of Domestic Fuelwood Consumption in Newfoundland	**DURATION**	September 1983 - March 1984
CONTRACT #	KH205-3-0044(OSC83-00366) P-263	**COST**	$67,450
CONTRACTOR	Northland Associates Ltd. P.O. Box 1734 St. John's, Newfoundland A1C 5P5	**SPONSOR**	Environment Canada
		SCIENTIFIC AUTHORITY	R.S. van Nostrand Nfld. Forest Research Centre Environment Canada P.O. Box 6028 St. John's, Newfoundland A1C 5X8 Tele.: (709) 772-4806

OBJECTIVE

To investigate the current and future demands for domestic fuelwood for the island of Newfoundland, with special emphasis on the Avalon Peninsula.

DESCRIPTION

The study will be comprised of four surveys:

(1) The major part of the study will consist of a survey of households throughout the Island to determine pattern of fuelwood use. This survey will be conducted by mailed questionnaire and telephone interview.

(2) Personal interviews will be conducted with each Unit Forester on the Island to collect additional information and gain an appreciation of the supply and demand problem peculiar to each Unit. The impressions from these interview will constitute part of the contractor's report.

(3) A survey will be conducted to identify and interview commercial fuelwood retailers on the Island.

(4) For the Avalon Peninsula alone, an assessment of fuelwood supply will be conducted.

Information required: The study will include, but not be restricted to, the following subjects for each Forest Management Unit Surveyed, and for the Island as a whole.

- The average annual usage in total and per household by type, form, and species. Type includes principal heating fuel, supplementary heating, fireplace, and other form includes roundwood, sawmill residues, and other. Species is either softwood or hardwood.
- The proportion of firewood cut and/or purchased by the user;
- The months most of the wood is cut or purchased;
- Prices charged for wood delivered and at roadside;
- Sources of fuelwood - company, crown or private land, sawmill, or fuelwood retailer;
- Type of wood harvester - merchantable, scrub etc.;
- Method of transportation and distances hauled.

Information required from fuelwood retailers will include:

- Current and average sales during the past five years;
- Quantities sold, separated by hardwood and softwood;
- 1982-83 selling prices delivered and at roadside;
- Sources of fuelwood, and distances hauled;
- Number of years in fuelwood retail trade;
- Trends in wood sales.

For the Avalon Peninsula alone, the following will be done in addition to the foregoing;

- Identify, classify, and delineate the major fuelwood supply areas;
- Estimate the annual allowable fuelwood cut from these areas;
- Estimate the actual annual fuelwood cut from these areas;
- Evaluate the nature and extent of damages and losses to the forest resource and forest industry caused by fuelwood cutting.
- Estimate the area that has been degraded by poor harvesting practices.

Survey Methods - A minimum of 5,000 mailed questionnaries will be distributed and a minimum of 4,000 telephone interviews will be conducted. The sampling system to be used for the mailed and telephone questionnaire must be of sound statistical design to obtain an accurate representation. Data on numbers of households in each community will be obtained from the latest summaries by Statistics Canada. All communities and municipalities with more than 500 households will be sampled. Approximately one-half of the total households surveyed will be from the Avalon Peninsula.

CONTINUED

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$67,450			$67,450

REPORTS

Northland Associates Ltd. 1984. "Domestic Fuelwood Consumption in Newfoundland," ENFOR Contractors' Report, Nfld Forest Research Centre. (in press)

STATUS AND COMMENT

Project completed.

PROJECT DATA SHEET # 431		**PROGRAM IDENTIFICATION**	4.3.1.3 Biomass Resource Assessment/ Forestry-Biomass Factors
TITLE	Access Data for the 1984 National Biomass Inventory	**DURATION**	July 1983 - January 1984
CONTRACT #	KH415-3-0156(05583-00053) P-265	**COST**	$56,588
CONTRACTOR	T.M. Thomson & Associates Ltd. 1006 Gouvernment Street Victoria, British Columbia V8W 1X7	**SPONSOR**	Environment Canada
PRINCIPAL INVESTIGATOR	R.G. Kind	**SCIENTIFIC AUTHORITY**	G.M. Bonnor Forestry Statistics and Systems Branch Canadian Forestry Service Department of the Environment Chalk River, Ontario K0J 1J0 Tele.: (613) 589-2880

OBJECTIVE

DESCRIPTION

The purpose of this project is to determine the present accessibility of the forest biomass in Canada. This accessibility is to be separated as to road, rail and water transportation systems. The Canadian Forestry Service will be supplied with a complete set of base maps indicating the extent of the three transportation systems. In addition, computer tapes containing the digitized transportation information for each province and territory will also to be supplied.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$56,588			$56,588

REPORTS

T.M. Thomson & Associates Ltd. "Access Data for 1984 National Biomass Inventory," contract KH415-3-0156, ENFOR P-265, Victoria, British Columbia, May 1984.

STATUS AND COMMENT

Project P-265 completed

84/12/07

PROJECT DATA SHEET # 432

TITLE Coordination of the National Forest Biomass Inventory Program and Writing Canada's Forest Biomass Inventory Report

CONTRACT # KH415-3-0105(OSS83-00021)
P-266

CONTRACTOR T.M. Thomson & Associates Ltd.
1006 Government Street
Victoria, British Columbia
V8W 1X7

PROGRAM IDENTIFICATION 4.3.1.3
Biomass Resource Assessment/
Forestry-Biomass Factors

DURATION May 1983 - March 1984

COST $40,000

SPONSOR Environment Canada

SCIENTIFIC AUTHORITY G.M. Bonnor
Canadian forestry Service
Chalk River, Ontario
KOJ OJ1
Tele.: (613) 589-2280

OBJECTIVE

DESCRIPTION

(1) Collect any outstanding tree data, from Canadian Forestry Service (CFS) establishments, for use in factor approach;
(2) assess need for additional tree biomass equations, and ensure that they are derived, for use in equation approach;
(3) develop methodology and procedures for application of factor approach to specified provincial/territorial data sets;
(4) develop methodology and procedures for application of equation approach to specified provincial data sets;
(5) determine extent, location and stratum of areas to be field sampled;
(6) inspect progress and procedures by contractors doing additional field sampling; and
(7) update critical-path-chart and advise Scientific Authority of problem areas.

If required:

1) Inspect data from contractors for accuracy and completeness, and advise Scientific Authority;
2) Validate and edit biomass data from factor approach and equation approach;
3) Update critical-path-chart and advise Scientific Authority of problem areas;
4) Produce tabular and map summaries of biomass data, by province/territory; check and validate; and,
5) Produce draft outline of final report.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$40,000			$40,000

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 433

TITLE Conversion of the Conventional Volumetric Inventory of New Brunswick to a Biomass Inventory for Inclusion in the National Forest Biomass Inventory

CONTRACT # KH209-3-0099(OSC83-00252)
P-268

CONTRACTOR Province of New Brunswick
Department of Natural Resources
Forest Management Branch
P.O. Box 6000
Fredericton, New Brunswick
E3B 5H1

PROGRAM IDENTIFICATION 4.3.1.3
Biomass Resource Assessment/
Forestry-Biomass Factors

DURATION July 1983 - January 1984

COST $36,000

SPONSOR Environment Canada

SCIENTIFIC AUTHORITY G.D. van Raalte
Environment Canada
Maritimes Forest Research Centre
Canada Forest Service
P.O. Box 4000
Fredericton, New Brunswick
E3B 5P7
Tele.: (506) 452-3519

OBJECTIVE

Convert the present volumetric inventory of the Province of New Brunswick to a Biomass Inventory, to CFRDS Standards, for inclusion in the National Forest Biomass Inventory.

DESCRIPTION

To implement the equation approach of converting the present inventory to a biomass inventory, average stand tables will be developed from existing inventory plot data (for each of which stand tables have already been calculated) and by strata within regions. Each stratum is a combination of cover type, maturity group, volume class and ownership/status class. Each stand table will list, by 2 cm dbh classes and species, the number of trees/ha., the dbh class mid points will rang from 2 cm to 46 cm. To each stand table derived above, tree biomass equations will be applied to calculate tree biomass by species and component. The equations will include dbh as the independent variable.

Area data from the Provincial Inventory will be applied to (merged with) the biomass values to produce, for each map sheet (cell), a listing of provincial classes (cover type, ownership etc.) with the attributes of "date of information", "area", and "biomass (t/Km^2) by component and species". This listing will be edited and verified, then converted to CFRDS specifications using the algorithms from the timber inventory summary. Results of a trial run, using data from a few cells, will be sent to the Forestry and Statistics Branch before final compilations.

Biomass estimates (total tree biomass, in t/Km^2, for species or coniferous/deciduous separation only), for non-productive forest such as swamp fringes will also be obtained.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$36,000			$36,000

REPORTS

None, all data on tape

STATUS AND COMMENT

Contract completed. All data on tape sent to Petawawa National Forestry Institute, FSSB, for inclusion in the National Forest Biomass Inventory. 84/11/29

PROJECT DATA SHEET #	435	**PROGRAM IDENTIFICATION**	4.3.1.3 Biomass Resource Assessment/ Forestry - Biomass Factors
TITLE	Conversion of the Conventional Volumetric Inventory of Nova Scotia to a Biomass Inventory for Inclusion in the National Forest Biomass Inventory	**DURATION**	August 1983 - March 1984
		COST	$20,000
CONTRACT #	KH209-3-0098(OSC83-00319) P-269	**SPONSOR**	Environment Canada
CONTRACTOR	Nova Scotia Department of Lands and Forests P.O. Box 68 Truro, Nova Scotia B2N 5B8	**SCIENTIFIC AUTHORITY**	G.D. van Raalte Canadian Forestry Service Environment Canada P.O. Box 4000 Fredericton, New Brunswick E3B 5P7 Tele.: (506) 452-3519

OBJECTIVE

Work under this contract will convert the present volumetric inventory of the Province to a biomass inventory, to CFRDS standards, for inclusion in the National Forest Biomass inventory.

DESCRIPTION

To implement the equation approach of converting the present inventory to a biomass inventory, the contractor will sort the PSP's by CFRDS compatible strata and cells. The tree biomass equations will be applied to the plot data to calculate plot biomass by species and components, and then compile average values for all plots in a stratum/cell group. Ownership may be omitted from this level of stratification. The average values will be merged with "area data" and "date-of-information", at which point the contractor will have generated a complete listing of records within cells, each record showing referencing (province and cell codes), classes (provincial) and attributes (date, area, biomass values, t/km by species and components). The records will be edited and validated. Species will be combined into CFRDS species groups. Classes will be converted into CFRDS classes with no "compression" of records necessary due to the earlier sorting of the PSP's.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$20,000			$20,000

REPORTS

None, all data on tape

STATUS AND COMMENT

Contract completed. All data on tape sent to Petawawa National Forestry Institute, FSSB, for inclusion in the National Forest Biomass Inventory 84/12/06

PROJECT DATA SHEET #	436	**PROGRAM IDENTIFICATION**	4.3.1.3 Biomass Resource Assessment/ Forestry-Biomass Factors
TITLE	Provision of Data Analysis Services for the Manitoba Forest Inventory on an "As and When requested" Basis	**DURATION**	November 1983 - March 1984
		COST	$43,000
CONTRACT #	KH505-3-0272(OSG83-00139) P-270	**SPONSOR**	Environment Canada
CONTRACTOR	Manitoba Data Services Tenth Floor 215 Garry Street Winnipeg, Manitoba R3C 3P3	**SCIENTIFIC AUTHORITY**	T. Singh Northern Forest Research Service Environment Canada 5320-122 Street Edmonton, Alberta T6H 3S5 Tele.: (403) 435-7210

OBJECTIVE

To derive forest biomass estimates for the inventoried forests of Manitoba, and supply them to the Forestry Statistics and Systems Branch at Chalk River, Ontario in prescribed format.

DESCRIPTION

1. Apply tree biomass equations (derived for provincial merchantability standards) to provincial plot data and calculate plot biomass values.
2. Generate biomass stand and stock tables on the basis of information contained in plot data.
3. Data from the additional field sampling under taken in the non-inventoried and non-sampled areas (P-278) to be applied to Manitoba provincial data base.
4. Derive estimates for sub-merchantable stand components using yield (or stand) tables, test the methodology, and add to the provincial data base.
5. Compile biomass totals using Manitoba classification system, by cell, using biomass averages from item 2 multiplied by provincial inventory area values, and add to resulting data from item 3 and 4.
6. Check, validate, and edit totals for the summary data in Manitoba format under item 5.
7. Convert biomass data to CFRDS specification by the procedures previously used for the timber inventory data.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$43,000			$43,000

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 437

TITLE Development of a comprehensive weight-based Inventory of Woody Forest Biomass for British Columbia

CONTRACT # KH603-3-0173(0SB83-00354)
P-271 & P-274

CONTRACTOR British Columbia Government
Ministry of Forests
31 Bastion Square
Victoria, British Columbia
V8W 1J1

PRINCIPAL INVESTIGATOR F. Hegyi

PROGRAM IDENTIFICATION 4.3.1.3
Biomass Resource Assessment/
Forestry-Biomass Factors

DURATION August 1983 - April 1984

COST $260,000

SPONSOR Environment Canada

SCIENTIFIC AUTHORITY G.H. Manning
Pacific Forest Research Centre
Canadian Forest Service
506 West Burnside Road
Victoria, British Columbia
V8Z 1M5
Tele.: (604) 388-3811

OBJECTIVE

Development of a comprehensive, weight-based inventory of woody forest biomass for British Columbia

DESCRIPTION

1. Derivation of eight biomass component equations, where biomass is a function of age and site. There will be separate equations for each species and for three regions (coast, northern and southern interior). This will involve the following additional tasks:
   (a) The establishment of approximately 200 photo and 50 ground samples in non-commercial, non-productive and alpine forest, in order to complete the sample base for all forest types. Complete compilation of all samples compatible with Canadian Forestry Statistics data base.
   (b) Using standard mensurational parameters, determine the biomass for each sample which consists of pure species; the biomass so determined is by eight components.
   (c) To determine the biomass, by components, for samples consisting of mixed species, adjustment coefficient will be derived for the pure species regression functions; in addition, the pure species estimates will be pro-rated on the basis of species composition.
   (d) Using the biomass, by components, determined for the 56,000 samples as outlined above, eight biomass components equations will be derived, where biomass is a function of age and site. These equations will be derived separately for species and regions.
2. Compilation of area summaries by major forest types (aggregates) on a map sheet bases, using codes and fields defined on pages 42-46, fields 1-19, in Canada's Forest Inventory, 1981.
3. Application of the appropriate biomass equations to the aggregate types, in order to produce biomass summary reports by map sheets, regions and Province. This phase of the work will include both crown land and Tree Farm Licences. Summaries will be made available in the Canadian Forest Resource Data Base compatible forms on a computer tape and in hard copy form.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$260,000			$260,000

REPORTS

"Development of Comprehension weight-based Inventory of Woody forest Biomass for B.C.," Contractor's Final report.

CONTINUED

STATUS AND COMMENT

Completed April 1984

84/12/06

PROJECT DATA SHEET #	438
TITLE	Collection of Forest Biomass Data on Unsurveyed Forest Lands in Ontario
CONTRACT #	KH415-3-0157(0SS83-00033) P-272
CONTRACTOR	Dendron Resource Surveys Ltd. Suite 206 880 Lady Ellen Place Ottawa, Ontario K1Z 5L9
PROGRAM IDENTIFICATION	4.3.1.3 Biomass Resource Assessment/ Forestry-Biomass Factors
DURATION	June 1983 - March 1984
COST	$49.999
SPONSOR	Environment
SCIENTIFIC AUTHORITY	G.M. Bonnor Canadian forestry Service Chalk River, Ontario KOJ 0J1 Tele.: (613) 589-2280

OBJECTIVE

To obtain and compile detailed plot data on unsurveyed forest lands in Ontario.

DESCRIPTION

Three populations are identified;
(a) Northern Ontario, the forest lands North of the Forest Resource Inventory (FRI) boundary;
(b) Southwest Ontario; Lake Huron and Lake Erie Districts;
(c) Central Ontario; all forest lands not covered by (a) and (b).
For each population, five strata will be identified. In each stratum, 50 sample plots will be located.
The strata will be as follows;
a) Northern Ontario: based on volume-species combination;
b) Southwest Ontario: working Group combinations;
c) Central Ontario: combinations of those FRI classes for which no volume estimates are available, e.g. Non-productive Forest, Treed Muskeg.
Maps will be made available to Contractor for selection of sample plot locations, which will be done as follows, for each province:
1) fifty forest type maps (or equivalent areas) will be selected at random;
2) on each map, five plot locations will be noted, one for each strater;
3) each plot location will be accessible by road, no more than 1.5 km from the road;
4) in Northern Ontario, any existing field data may, with approval by Scientific Authority, be used in replacement of field plots.
5) Plots will be established and measured, as follows:
- Plots will not be closer than one hundred (100) metres to a disturbance e.g. road right-of-way.
- Plots will be circular with a radius of 2.825 m (area, 25m).
- Trees 10.2 cm d.b.h. will be recorded by species, diameter measured to the nearest tenth of a centimetre and height will be estimated to the nearest metre. (breast height = 1.3 m).
- Trees and shrubs less than 10.2 cm d.b.h. will be recorded by species and 2 cm diameter classes (2.2 - 4.2 cm, 4.2 - 6.2 cm, 6.2 - 8.2 cm, 8.2 - 10.2 cm). Average height by species and diameter class will be estimated to the nearest metre.
- Information will be recorded on the form provided (copy attached);

6) the field data will be edited and verified, and transcribed onto magnetic tape.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$49,999			$49,999

REPORTS

CONTINUED

STATUS AND COMMENT

PROJECT DATA SHEET # 439

TITLE
Performing Statistical Compilations of Forest Land Areas by Township

CONTRACT #
KH505-3-0383(OSG83-00181)
P-273

CONTRACTOR
J. Harder
205-1628 48 Street
Edmonton, Alberta
T6L 5T2

PROGRAM IDENTIFICATION
4.3.1.3
Biomass Resource Assessment/
Forestry-Biomass Factors

DURATION
February 1984 - March 1984

COST
$1,500

SPONSOR
Environment Canada

SCIENTIFIC AUTHORITY
W.C. Moore
Northern Forest Research Centre
Canadian Forestry Service
Environment Canada
5320-122 Street
Edmonton, Alberta
T6H 3S5
Tele.: (403) 435-7247

OBJECTIVE

To perform statistical compilations of forest land areas by township for all the non-inventoried parkland and prairie strata of the three prairie provinces.

DESCRIPTION

The forest cover theme (green area) on 1:250,000 scale National Topographic Series maps was dot-counted by township to provide location-specific forest area data for the Canadian Forest Resource Data System. The appropriate mapsheets and working accommodation were provided by the sponsor. Accuracy in location-specific derivations and compilations essential as results will later be incorporated into National forest and biomass resource statistics tabulations.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$1,500			$1,500

REPORTS

Statistical printouts by province and data tape forwarded to the forestry statistics and systems branch of the Canadian Forestry Service at Chalk River, Ontario

STATUS AND COMMENT

Complete.
Mapsheets are as current as the aerial photography used to prepare them. Some of this dated back to the 1950's. Tabulations to be updated with landsat imagery in FY 1984-85.
84/12/06

PROJECT DATA SHEET # 441

TITLE Evaluation of Forestry Biomass in the non-inventoried forest area of the province of Quebec

CONTRACT # KH303-3-C-023(OSD83-00083)
P-283

CONTRACTOR Le Groupe Dryade Ltée
642 ouest, boul. St-Cyrille
Québec (Québec)
G1S 1S8

PROGRAM IDENTIFICATION 4.3.1.3
Biomass Resource Assessment/
Forestry - Biomass Residue

DURATION May 1983 - March 1984

COST $250,000

SPONSOR Environment Canada

SCIENTIFIC AUTHORITY J. Beaubien
Laurentian Forest Research Centre
Canadian Forest Service
1080 Route du Vallon
Ste-Foy, Québec
G1V 4C7

OBJECTIVE

An inventory of the forest biomass in the non-inventoried forest area of Quebec will be carried out as part of the ENFOR program. This will include the preparation of both detailed maps, as well as estimates of the biomass present in this area.

DESCRIPTION

The work program will include two concurrent parts;

Part 1 (Mapping of Non-Inventoried Area: 400,000 Km)

(i) Preparation of a workplan and the logistics for flights over the forestry area.
(ii) Acquisition of base information using the LANDSAT satellite.
(iii) Flights over the forestry area and preliminary assessment of the LANDSAT Data.
(iv) Analysis of the LANDSAT data and comparison with both visual and photographic observations made during the flights.
(v) The refinement of the LANDSAT data.
(vi) The photo interpretation of the area.
(vii) Cartography: The area will be mapped at a scale of 1:125,000 for the southern part and 1:250,000 for the northern part and the results presented to the "Service de l'inventaire forestier (SIF)" of Quebec. The maps will be digitized for a data bank.

Part 2 (Estimation of Forestry Biomass)

(i) Based on the LANDSAT data, 190 test section of 200 m will be identified for the evaluation of biomass present.
(ii) Sample data from each test section will be obtained and analyzed.
(iii) LANDSAT data will be analyzed to obtain a correlation with data obtained.
(iv) Photo-interpretation - the photos will be interpreted to correlate this data with that obtained above.
(v) Mapping - the various types of biomass present will be identified on maps.
(vi) Plotting - the various data obtained for the area will be plotted.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$250,000			$250,000

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET #	451
TITLE	National Forest Biomass Inventory
CONTRACT #	OGR83-00107 OEZ82-07636 1) (OGR83-00107) P-276 2) (OEZ82-07636) P-276
CONTRACTOR	Dendron Resource Surveys Ltd. Box 6493, Station J Ottawa, Ontario K2A 3Y6 J. Proudfoot The Laurier Group 275 Slater Street Ottawa, Ontario K1P 5H9

PROGRAM IDENTIFICATION	4.3.1.3 Biomass Resource Assessment/ Biomass Factors
DURATION	April 1983 - March 1984
COST	$45,800
SPONSOR	Environment Canada
SCIENTIFIC AUTHORITY	G.M. Bonnor Forestry Statistics & Systems Branch Canadian Forestry Service Chalk River, Ontario KOJ 1JO Tele.: (613) 995-7010

OBJECTIVE

DESCRIPTION

OGR83-00107

In the Province of Quebec, for each of three forest strata labelled "alder", "moist barren" and "humid barren":

1. Data for individual trees in approximately 50 sample plots. The data is to include for each plot:
    - A) for trees 9.0 cm dbh and larger: individual tree species, dbh and height;
    - B) for trees less than 9.0 cm dbh: number of trees by species and 2 cm classes (4 classes);
    - C) location of plot (Northern and Southern line).

Alternatives to these specifications must be approved by the Scientific Authority.

2. Two tables of average biomass values, in dry t/ha, by species and 8 components. One table for each line.
3. An estimate of the relative size of each stratum area within each line.

OEZ82-07636

Using data made available by the FSSB, and detiled specifications, flow charts and diagrams already developed, the Contractor will develop software and apply the software to data from:

1) Ontario
2) Saskatchewan
3) Alberta

for the estimation of forest biomass in these provinces.

The available data are in the Canadian Forest Resource Data System format and comprise, in essence, volume data. The approach used to obtain biomass from these data is termed the Factor Approach.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84 1983-84	$15,800 $30,000			$15,800 $45,800

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 453		**PROGRAM IDENTIFICATION**	4.3.1.4 Biomass Resource Assessment/ Forestry-Energy plantations productivity
TITLE	Energy Biomass Yield by Selected Full-Tree Harvesting Methods in Frozen Conditions	**DURATION**	February 1984 - April 1984
CONTRACT #	KH405-3-0463(OSE83-00344) P-295	**COST**	$19,780
CONTRACTOR	Forest Engineering Research Institute of Canada 143 Place Frontenac Pointe Claire, Quebec H9R 4Z7	**SPONSOR**	Environment Canada (ENFOR PROGRAM)
		SCIENTIFIC AUTHORITY	J.D. Johnson Great Lakes Forest Research Centre Canadian Forestry Service Environment Canada P.O. Box 490 Sault Ste. Marie, Ontario P6A 5M7 Tele.: (705) 949-9461

OBJECTIVE

To provide estimates of the quantity of biomass recovered with each of the full tree harvesting methods (in green tonnes per green tonne or cubic meter of wood merchantable for conventional forest products)
To identify the relationship between the number of live branches lost in primary transportation (counting branches is much less expensive and if it gives reasonable accuracy it would therefore be more desirable).
To identify the effect of season on biomass yield at roadside.
To gather data for a volume table.

DESCRIPTION

Phase I
Field data will be collected under two different full-tree harvesting systems. Various tree and biomass variables will be measured. A report is to be submitted at the end of Phase I, including a summary of the collection process for all variables measured and a description of any problems encountered in this process. This report will be called the Interim report.
Phase II
Data collection under Phase I will be analyzed. The relationship of biomass to various tree parameters will be calculated. Biomass recovery will be calculated.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$19,780			$19,780

REPORTS

Phase I - Interim Report. Received March 12, 1984
Phase II - Final Report - "Jack Pine Biomass Yield Study - Winter Phase"
Received May 16, 1984

CONTINUED

STATUS AND COMMENT

A similar contract under unfrozen (summer) conditions was awarded to FERIC on July 18, 1984. (KH405-4-0077). This contract also includes a Jack Pine biomass transportation study and a final report summarizing the economics of full-tree Jack Pine harvesting. This contract has a value of $29,805. The final report is due March 29, 1985 84/12/06

PROJECT DATA SHEET # 216

TITLE Assessment of Lunaria as a Prospective Crop for Fuels and Industrial Oils

CONTRACT # 345Z.1843-1-ER01 (05Z81-58)

CONTRACTOR
Enersearch Federated Cooperative Ltd.
401 - 22nd Street
Saskatoon, Saskatchewan
S7K 3M9

PRINCIPAL INVESTIGATOR Brian Dykes
Tele.: (306) 224-3300

PROGRAM IDENTIFICATION 4.3.1.7
Biomass Resource Assessment/ Agriculture-Energy Crops

DURATION October 1982 - January 1984

COST $12,000

SPONSOR Agriculture Canada

SCIENTIFIC AUTHORITY
M. Stumborg
Agriculture Canada
Research Branch
Research Station
Swift Current, Saskatchewan
S9H 3X2
Tele.: (306) 733-4621

OBJECTIVE

To assess Lunaria as a prospective crop for fuels and industrial oils.

DESCRIPTION

Phase 1

1. The contractor shall conduct a comprehensive literature search on Lunaria sp. related to its agronomic properties and potential uses as industrial chemicals and fuels.
2. The contractor shall obtain sufficient quantity of Lunaria annua and biennis to initiate laboratory analysis and plant field test plots.
3. The contractor shall perform laboratory analyses including extraction of the seed oil and the determination of % content and composition by GLC of its methyl esters, viscosities, density, and calorific value.
4. The contractor shall examine the residual meal to determine the nature and levels of the glucosinolates present, the protein, crude fibre and ash content, ADF/NDF analysis and amino acid composition of the meal.

Phase 2

1. The contractor will design a field trial test plan in collaboration with the scientific authority and other Agriculture Canada staff as required. The test plan will include details of the planting configuration and assessment of potential yield, agronomic properties such as maturity, height, lodging, or others as mutually agreed to by the scientific authority and the contractor. The field trials will be sufficiently large to provide a seed supply required for potential future large scale field trials.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1982-84	$ 8,000	$4,000		$12,000

REPORTS

The final report was received January 1984.

STATUS AND COMMENT

The contract was terminated January 1984. Plant material variability and unsuitability for prairie conditions proved to be serious concerns. 84/12/04

PROJECT DATA SHEET # 217

TITLE Assessment of Milkweed as a Potential Renewable Fuel Crop

CONTRACT # 34SZ.1843-1-ER02 (OSZ81-69)

CONTRACTOR
Enersearch Federated
Cooperative Ltd.
401 - 22nd Street
Saskatoon, Saskatchewan
S7K 3M9

PRINCIPAL INVESTIGATOR
Brian Dykes
Tele.: (306) 244-3300

PROGRAM IDENTIFICATION 4.3.1.7 Biomass Resource Assessment/ Agriculture-Energy Crops

DURATION October 1981 - November 1983

COST $106,000

SPONSOR Agriculture Canada

SCIENTIFIC AUTHORITY
M. Stumborg
Agriculture Canada, Research
Branch, Research Station
Swift Current, Saskatchewan
S9H 3X2
Tele.: (306) 773-4621

OBJECTIVE

To assess the potential of milkweed as an energy crop.

DESCRIPTION

Phase 1 The contractor will design a field trial test plan in collaboration with the scientific authority and other Agriculture Canada staff as required. The test plan will be designed within the bounds of the milkweed seed plantings that were established by the contractor during the fall of 1980. The test plan will include details of agronomic practices (e.g. optimum levels of fertilizer, irrigation, weed control, etc. versus non-intensive levels of agronomic inputs, and multiple harvests versus single harvest), agronomic properties (e.g. maturity, yield, soil analysis, dry matter, etc.) andchemical properties(e.g. fiber, ash, in vitro digestibility, protein content of the residual biomass, extractable crude oil, C/H/N analysis, calorific content, and if possible chemical composition and molecular weight distribution).

Phase 2 The contractor will design an animal feeding trial test plan in collaboration with the scientific authority and other Agriculture Canada staff as required. The test plan will be designed to investigate the feed value of oil extracted milkweed residue in terms of palatability, toxicity, digestibility, or other parameters.

Phase 3 The contractor will: 1) carry out the field trial test plan as described in Phase 1; 2) carry out the animal feeding trial test plan as described in Phase 2; 3) carry out a detailed evaluation and analysis of the oil fraction at each of two separate laboratories (the oil will be assessed qualitatively and quantitatively as a refinery feedstock for liquid fuel or chemical production); 4) assess the residual plant material in terms of yield, availability, potential value, and byproduct utilization as protein, fibre or liquid fuels; 5) carry out an initial selection of plant breeding stock based on the morphology of the plan and wild colony of which it is a member; 6) collect seed from wild colonies to assist in further establishing replicated plots for possible future yield and agronomic studies and; 7) make preliminary suggestions on farm cultivation, harvesting and extraction, industrial extraction and refinery, end-uses, marketing and future R&D requirements.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1981-82	$34,000			$ 34,000
1982-83	$32,000			$ 66,000
1983-84	$40,000			$106,000

REPORTS

A final report will be issued December 1, 1984, and will be made available through CISTI Library.

CONTINUED

STATUS AND COMMENT

Contract terminates November 30, 1984. The research pointed out serious concerns regarding the use of milkweed as a multiuse biomass crop.

84/12/04

PROJECT DATA SHEET # 305

TITLE Assessment of the Potential of Growing Unconventional "Energy Crops" or Multi-use Crops on Saline or Marginal Land

CONTRACT # 01843-1-ER05 (DSZ81-00121)

CONTRACTOR
Saskatchewan Research Council
30 Campus Drive
Saskatoon, Saskatchewan
S7H 0X1

PRINCIPAL INVESTIGATOR
E. Coxworth
Tel.: (306) 664-5400

PROGRAM IDENTIFICATION
4.3.1.7
Biomass Resource Assessment/
Agriculture - Energy Crops

DURATION April 1981 - April 1985

COST $541,252

SPONSOR Agriculture Canada

SCIENTIFIC AUTHORITY
W.L. Crowle
Research Station
Agriculture Canada
107 Science Crescent
Saskatoon, Saskatchewan
S7N 0X2
Tel.: (306) 343-8214

OBJECTIVE

To expand current agronomic investigations (Contract ER05) on kochia in particular, plus slender wheat grass, sweet clover, fodder beet and barley (control) that have shown tolerance to saline soils. Alfalfa to be grown as an interceptor crop at the base of knolls to control spread of saline seeps. to evaluate protein rich fractions as animal feed and cellulose rich fractions for enzymatic hydrolysis and conversion to ethanol.

DESCRIPTION

Phase I The contractor will design a field trial test plan for the growing of potential agriculture liquid fuel crops or multi-use crops on saline or marginal lands. These crops will include kochia, Jerusalem artichoke, fodder beet, and the others which have been established as a current SRC in-house project. Possible criteria for evaluation will be stand establishment, salinity tolerance, yield, agronomic benefits, and projected usefulness of end products.
Phase II Those plants identified in the Phase I interim report will be planted on replicated field plots. Agronomic properties to be examined are to include planting densities, yields, levels of salinity tolerance, germination, and plant development. Six samples of material are to be made from the plots at different times to determine above-ground dry matter yield and composition.
Phase III Using feedstocks from plant species grown during Phase II, the contractor will perform the following investigations:
1) Production and isolation of sources of cellulolytic enzymes.
2) Design fermentation systems to digest cellulose and hemicellulose.
3) Examine pretreatment methods both chemical and physical.
4) Analyse the hydrolysate and determine rates.
Phase IV The contractor will perform studies of cell wall chemistry, structure and biology, microbiology of enzyme transformation and physico-chemical transformation of forages, crop residues and other energy crops identified in Phase I to determine why one material is more digestible than another and what are the specific effects of chemical or biological agents in improving digestibility.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1981-82	$100,000	$ 48,002		$148,002
1982-83	$125,000	$ 61,250		$334,252
1983-84	$ 72,000	$ 70,000		$476,252
1984-85	$ 65,000			$541,252

CONTINUED

REPORTS

Twenty copies of the final report, Volumes II and III, are completed and in the hands of the Scientific Authority. Volume I (agronomic Study) has been completed and the report will be printed in September.

STATUS AND COMMENT

The completion of Volume I (see above) will terminate the contract. All volumes will then be forwarded.

84/11/29

PROJECT DATA SHEET #	311	**PROGRAM IDENTIFICATION**	4.3.1.7 Biomass Resource Assessment/ Agriculture - Energy Crops
TITLE	Rye-Corn Sequences for Biomass Production	**DURATION**	June 1982 - March 1985
CONTRACT #	01916-2-ER23 (OSU82-00089)	**COST**	$198,534
CONTRACTOR	University of Guelph Dept. Crop Science Guelph, Ontario N1G 2W1	**SPONSOR**	Agriculture Canada
PRINCIPAL INVESTIGATOR	T.B. Daynard	**SCIENTIFIC AUTHORITY**	J.M. Elliot Agriculture Canada Research Branch Pesearch Station Delhi, Ontario N4B 2W9 Tel.: (519) 582-1950

OBJECTIVE

To grow, measure and maximize biomass yield by using two crops, winter rye followed by corn during each year. Some of the effects of this sequence to be evaluated are: the effects on soil, effects of seeding into alternate stubbles, evaluate seeding methods of rye after once over discing or aerial seeding. In addition, other crop culture requirements will be monitored such as fertility, weed control and insect control.

DESCRIPTION

1. To obtain biomass yields from a two-crop sequence of winter-rye & corn & evaluate cultural alternatives and requirements for maximizing and/or optimizing the total dry matter yield.
2. To measure effects of the cropping sequence on the physical quality of the soil and determine the effects of the soil structure created by rye on photosynthesis and biomass yield of corn.
3. To evaluate the utility of sorghum for inclusion in a double-crop sequence with winter rye for biomass production.
4. To determine the liquefaction pyrolysis product yield of low-lignin biomass from rye and corn.
5. To provide an estimate of the agronomic costs of production for the projection of feedstock costs.
6. To provide proximate chemical analyses and calculate potential yields of ethanol, methanol, pyrolytic oils and oven-dry biomass on a hectare basis.
7. To provide a complete economic and energy input-output evaluation of rye-corn for biomass productivity and the potential liquid-fuel yields.
8. To evaluate the utility of sunflower for inclusion in a double-crop sequence with Winter rye for biomass production.
9. To provide an estimate of economics and energy input-outputs of rye-sorghum and rye-sunflower sequences for biomass productivity and the potential liquid fuel yields.
10. To provide information on procedures for storing wet biomass from rye-corn, rye-sorghum & rye/sunflower as silage in horizontal silos, for the preservation during time intervals between harvesting and utilization.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1982-83 1983-84 1984-85	$59,627 $64,225 $74,682			$ 59,627 $123,852 $198,534

REPORTS

Two annual reports and thirteen progress reports received on Rye-Corn Sequence for biomass production, since inception.

CONTINUED

STATUS AND COMMENT

Progress is quite satisfactory. J.M. Elliott 84/12/06

PROJECT DATA SHEET # 315

TITLE
Assessment of the Agronomic, Technical & Economic Feasibility of Producing Jerusalem Artichokes for Energy Crop

CONTRACT # 01843-1-ER20 (OSZ82-00022)

CONTRACTOR
SunRoot Energy Limited
Suite 3400
The Exchange Tower
2 First Canadian Place
Toronto, Ontario
M5X 1J3

PRINCIPAL INVESTIGATOR P.W. Billingsley

PROGRAM IDENTIFICATION
4.3.1.7
Biomass Resource Assessment/
Agriculture - Energy Crops

DURATION April 1982 - April 1985

COST $251,912

SPONSOR Agriculture Canada

SCIENTIFIC AUTHORITY
Gary Hergert
Engineering & Statistical
Research Institute
Research Branch
Agriculture Canada
Building 94
Ottawa, Ontario
K1A OC6
Tel.: 995-3151

OBJECTIVE

To develop and evaluate the equipment needed for growing Jerusalem artichokes. To evaluate the energy and economic aspects of growing Jerusalem artichokes. To develop and evaluate the agronomic practices to maximize output and profitability from tops and tubers. Details are to include planter and seed slicer development, harvesting technique, fertilization, plant densities, and weed control. to report on the economics and feasibility of feeding sugar extraction byproducts to cattle and pigs.

DESCRIPTION

1. Investigate, implement and develop the agronomic aspects of the crop including: (a) variety evaluations, (b) site evaluations, (c) yield evaluation of foliage and tubers, (d) assessment of the effect of fertilizer and pH levels on the yield of the Jerusalem Artichoke.
2. Measure the energy inputs of producing the crop and report on the economic feasibility of producing the crop by: (a) recording the fuel usage during operations, (b) recording fertilizer usage, (c) measuring yields, (d) recording records of manpower inputs.
3. Investigate, evaluate and develop the equipment needs for the crop by: (a) testing existing equipment, (b) developing or modifying equipment, in cooperation with Canadian manufacturers where possible, to suit the special needs of the crop, (c) evaluating and reporting on the capacity and the efficiency of the equipment.
4. Demonstrate the production system on at least 12 ha the first year and 40 ha the second year with auxiliary plantings of at least 1 ha in Eastern Ontario and 1 ha in Northern Ontario.
5. Evaluate the feasibility of feeding the by-product of fermentation to cattle and to pigs.
6. Assess the sugar and feed composition values at different stages of growth for the tops and tubers, and of the fermentation mash.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1982-83 1983-84 1984-85	$139,760 $ 88,152 $ 24,000			$139,760 $227,912 $251,912

REPORTS

CONTINUED

STATUS AND COMMENT

Limited data was collected from the initial 12 ha planting. An additional 25 ha was planted in 1983 and sugar and yield data collected. A feed trial was carried out with J.A. tops. Evaluation of combination top and tuber harvest was carried out. An additional 10 ha was planted in spring 1984 and evaluation of tops and harvest techniques carried out. Use of tops for alcohol production looks promising. 84/12/06

PROJECT DATA SHEET # 369		**PROGRAM IDENTIFICATION**	4.3.1.7 Biomass Resource Assessment/ Agriculture-Energy crops
TITLE	Testing & Assessment of the SUKUP Biomaster Crop Residue Drying System	**DURATION**	November 1981 - March 1984
CONTRACT #	01843-1-ER07 (05Z81-00092)	**COST**	$49,000
CONTRACTOR	Forintek Canada Corp. Eastern Laboratory 800 Montreal Road Ottawa, Ontario K1G 3Z5	**SPONSOR**	Agriculture Canada
		SCIENTIFIC AUTHORITY	D. Marshall Engineering and Statistical Research Institute Research Branch Agriculture Canada Ottawa, Ontario K1A 0C6 Tele.: (613) 995-9671

OBJECTIVE

To carry out detailed studies of the SUKUP Biomaster system including the following qualitative and quantitative evaluations.

Qualitative: i) general performance and case of operation, ii) degree of supervision required, iii) suitability of non-technical supervision/operation, iv) safety, v) anticipated problems when operating in a farm setting.

Quantitative: i) analyse the combustion products: gas analysis, particulates, condensible organics content, ii) determine the range of operating temperatures, iii) estimate the thermal efficiency of the unit, iv) determine the mass throughput of the biomass feedstock and combustion products (mass balance) and establish effective turndown ratio.

DESCRIPTION

Phase I Installation - This phase involves the manpower and material costs required to physically install the SUKUP unit at Forintek, and to make appropriate modifications which are necessary for process monitoring and sampling. Installation of the analytical train for condensation of organic products from the off-gas prior to gas chromatographic analysis would also occur during this initial phase.

Phase II Commissioning - This initial operation and shakedown would commence after installation in order to familiarize technicians with operating procedures and test sampling techniques. This would involve several trial runs on typical base fuel.

Phase III Testing - The actual experimental runs would commence after routine operating and sampling procedures had been established. It is proposed that two typical agricultural residues, cereal straw and corn stover, be used initially.

Phase IV Analysis of data and preparation of reports.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1981-82	$17,000			$17,000
1982-83	$30,000			$47,000
1983-84	$ 2,000			$49,000

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 458		**PROGRAM IDENTIFICATION**	4.3.1.7 Biomass Resource Assesment/ Agriculture-Energy Crops
TITLE	Potential of Cattails as an Energy Crop	**DURATION**	April 1982 - March 1984
CONTRACT #	E1038	**COST**	$171,000
CONTRACTOR	Saskatchewan Research Council Saskatoon, Saskatchewan	**SPONSOR**	Agriculture Canada
PRINCIPAL INVESTIGATOR	G. Lakshman	**SCIENTIFIC AUTHORITY**	G. Knipfel Swift Current Research Sta. Research Branch Agriculture Canada P.O. Box 1030 Swift Current, Saskatchewan S9H 3X3 Tele.: (306) 773-4621

OBJECTIVE

DESCRIPTION

To evaluate the cellulose, hemicellulose, starch, and sugar in cattail rhizomes and leaves and determine their variation with season, growth stage and nutrient status. Determine the effects of nitrogen, phosphorous and photosynthetic activity on the nature and degree of carbohydrate storage in the plant. To evaluate cattails availability on natural wetlands and on cultivated experimental plots from natural stands, marginal lands, peat lands and moderately saline soils. Evaluate, using controlled bench tests, the effect of cold treatment, pretreatment with algal exudates (enzymes) and composting for converting starch and cellulose to fermentable sugars.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1982-83 1983-84	$135,000 $ 36,000			$135,000 $171,000

REPORTS

STATUS AND COMMENT

ENVIRONMENTAL EFFECTS

Forestry - Silvicultural and Harvest Impacts

Forestry - Conversion Technology Impacts

Agricultural - Agricultural and Harvesting Impacts

Agricultural - Conversion Technology Impacts

Peat - Harvesting

Peat - Conversion Technology

PROJECT DATA SHEET #	82	**PROGRAM IDENTIFICATION**	4.3.2.1 Biomass Environmental Effects/ Forestry-Silvicultural and Harvesting Impacts
TITLE	Nature and Extent of the Impact of Forest Biomass Harvesting on the Forest Environment.		
CONTRACT #	KL004-9-0012 (OSD79-000014) KH303-3-C-003(OSD82-00187) P-95, P-155	**DURATION**	June 1979 - March 1984
		COST	$319,479
CONTRACTOR	Le Groupe Dryade Ltée 642, boul. St. Cyrille O. Québec, Québec. G1S 1S8	**SPONSOR**	Environment Canada
		SCIENTIFIC AUTHORITY	Gilles Frisque Laurentian Forest Research Centre Canadian Forestry Service 1080 route du Vallon Ste-Foy, Québec G1V 4C7 Tl.: (418) 653-2143
PRINCIPAL INVESTIGATOR	Jean-Louis Blouin Tél.: (418) 681-0687		

OBJECTIVE

To identify and assess the relative importance of forest environmental potential changes brought about by forest biomass harvest. To estimate the time required for normal ecosystem recovery. To prepare preliminary guidelines for environmental monitoring and protection.

DESCRIPTION

The principal objective of the study entails the identification (based on the literature concerning potential impacts resulting from forest biomass harvesting) of the variables pertaining to the forest environment that are most susceptible to being influenced by such a harvesting. It also entails the quantification, if possible, of the intensity of the modifications these variables undergo. The former task has permitted the identification of those elements within a monitoring program that are feasible for use as indicators of the impacts on the forest environment resulting from biomass harvesting. The study outline adopted consists of six phases shown.

- Selective bibliographical review
- Information treatment
- Matrix of simple (natural) correlations
- CNYR Matrix of impacts (1972)
- Flow-diagram of interrelationships
- Simplified or thematic flow-diagrams
- Strategy, application procedures and monitoring. Pre- and postcut inventory of environmental variables.

FUNDING

FISCAL YEAR	SPONSOR	IN-HOUSE		CUMULATIVE TOTAL
1979-80	$ 40,000			$40,000
1980-81	$120,000			$160,000
1981-82	$ 46,000			$206,000
1982-83	$ 59,979	$ 2,000		$267,979
1983-84	$ 50,000	$ 1,500		$319,479

REPORTS

"Evaluation of Potential Impacts of Forest Biomass Harvesting", by Le Groupe Dryade, August 1980. ENFOR Project P-95, LAU-X-45E (Available from ENFOR Secretariat and the Energy Library, CISTI).
"Évaluation des impacts potentiels de la récolte de la biomasse forestière," par Le Groupe Dryade Ltée, août 1980. Projet ENFOR P-95, LAU-X-45 (Disponible au Secrétariat ENFOR et ICIST - Section d'énergie).

CONTINUED

STATUS AND COMMENT

This project is now completed. A final report will be available in the coming months and will summarize field results obtained throughout the study period. 84/12/03

PROJECT DATA SHEET # 95

TITLE Modelling of the Long-term Consequences of Intensive Biomass Harvesting on Soil Fertility and Biomass Production.

CONTRACT # KL011-9-0006(OSS79-00060)
P-71, P-197

CONTRACTOR University of British Columbia
Faculty of Forestry
Vancouver, B.C.
V6T 1W5

PRINCIPAL INVESTIGATOR J.P. Kimmins
Tel.: (604) 228-4701

PROGRAM IDENTIFICATION 4.3.2.1
Environmental Effects/Forestry
-Silvicultural & Harvest Impacts

DURATION April 1979 - March 1984

COST $459,812

SPONSOR Environment Canada

SCIENTIFIC AUTHORITY L. Chatarpaul
Canadian Forestry Service
Petawawa National Forest Institute
Chalk River, Ont. KOJ 1J0
(613) 589-2880

OBJECTIVE

To refine existing computer model to render it a useful practical tool for forest management planning.
To obtain data from three types of forest environment to calibrate, validate and refine the model.

DESCRIPTION

Forest biomass in a sequence of stands varying over the age range expected in a managed forest will be estimated using existing allometric regressions (these will be tested before acceptance). Minor vegetation biomass will be measured by clipping-plots. Nutrient content of all biomass components, and nutrient cycling by litter-fall, leaching, internal cycling and decomposition will be investigated by standard techniques. Estimates of soil fertility and rooting depth will be obtained. Additional parameters will be investigated as demanded by the refined computer model. This work will be conducted at coastal low elevation, coastal high elevation and interior sub-boreal forest locations. Data from other Canadian forest environments will be used where possible.

FUNDING

FISCAL YEAR	SPONSOR	IN-HOUSE		CUMULATIVE TOTAL
1979-80	$ 50,803			$ 50,000
1980-81	$ 68,808			$119,611
1981-82	$168,200			$287,811
1982-83	$162,097	$ 5,000		$454,908
1983-84	$ 2,604	$ 2,300		$459,812

REPORTS

Interim reports held by scientific authority.

STATUS AND COMMENT

Phase three of this project is referenced as ENFOR P-197, P-285

84/12/03

PROJECT DATA SHEET # 276		**PROGRAM IDENTIFICATION**	4.3.2.1 Environmental Effects/ Forestry - Silvicultural and Harvest Impacts
TITLE	Impact of Harvesting Mature Trees by Whole-Tree Method on the Microbiology, Organic Matter & Nitrogen Transformations of a Forest Soil	**DURATION**	May 1981 - March 1984
		COST	$139,593
CONTRACT #	KL011-1-0010 (DSS81-00040) P-199	**SPONSOR**	Environment Canada
CONTRACTOR	University of Guelph Guelpn, Ontario N1G 2W1	**SCIENTIFIC AUTHORITY**	L. Chatarpaul Canadian Forestry Service Environment Canada Petawawa National Forestry Institute CHALK RIVER, Ontario KOJ 1J0 Tele.: (613) 589-2880
PRINCIPAL INVESTIGATOR	J.B. Robinson Dept. of Environmental Biology		

OBJECTIVE

To understand the effects of whole-tree harvesting on the soil microorganisms and processes expecially those concerned with nitrogen transformations to provide a sound basis for designing forest soil management techniques aimed at the maintenance of site productivity.

DESCRIPTION

1. Review and report on the existing information about the impact of intensive forest managment practices on soil microbiology and processes especially those concerned with organic matter and nitrogen transformation.
2. Selection of a suitable forest site and the establishment of experimental plots.
3. Determine relative numbers of various groups of bacteria important in the N cycle as affected by harvest treatment including amonifiers, nitrifiers and denitrifiers. Their distribution down the soil profile will also be determined.
4. Characterize soils as to changes in organic matter content and changes in the rate of decomposition and mineral composition as determined by burying litter in bags and also by measuring gross soil respiration and analysing decomposed material.
5. Determine process rates of nitrification(by soil perfusion or a suitable method) and amonification (by incubation) for soils at least 3 times per year.
6. As required, obtain soil samples for chemical analysis (N, P, K, Ca, Mg, Mn, B, Cu, An, Fe) and record temperature, moisture, pH and CEC.
7. Conduct laboratory experiments on the effects of such factors as pH, temperature, moisture organic matter on the microbiology and related processes in the affected soils.

FUNDING

FISCAL YEAR	SPONSOR	IN-HOUSE		CUMULATIVE TOTAL
1981-82	$38,410			$ 38,410
1982-83	$42,903			$ 81,313
1983-84	$39,980	$18,300		$139,593

CONTINUED

REPORTS

HENDRICKSON O., ROBINSON J.B., AND CHATARPAUL L., "The Microbiology of Forest Soils: A Literature Review", CFS Inf. Rep. PI-X-19, 1983.

HENDRICKSON O., CHATARPAUL L., and ROBINSON J.B., "Effects of two Methods of Timber Harvesting on Microbial processes in Forest Soil", Soil Sci. Soc. Am. J. (in press), 1984.

HENDRICKSON O., and ROBINSON J.B., "Effects of roots and Litter on Mineralization Processes in Forest Soil", Plant and Soil (in press), 1984.

HENDRICKSON O., CHATARPAUL L., and ROBINSON J.B., "Effects of Physical and Chemical Treatments on Forest Soil Mineralization Rates", For. Sci. (in press), 1984.

HENDRICKSON O., ROBINSON J.B. and RACHAR D., "Effects of Two Harvesting Methods on Biological and Chemical Properties of Forest Soil", Fifth Bioenergy Seminar, Ottawa, Ontario, 1984.

CHATARPAUL L., BURGESS D., and HENDRICKSON O., "A comparison of Biomass and Nutrient Removed in Whole Tree and Conventional (stem only) Harvesting", Fifth Bioenergy Seminar, Ottawa, Ontario, 1984.

STATUS AND COMMENT

PROJECT DATA SHEET # 430		**PROGRAM IDENTIFICATION**	4.3.2.1 Environmental Effects/ Forestry-Silvicultural and Harvest Impacts
TITLE	Calibration of the FORCYTE Growth Model		
CONTRACT #	KH205-3-0042(OSC83-00461) P-264	**DURATION**	November 1983 - March 1986
		COST	$120,500
CONTRACTOR	Northland Associates Ltd. P.O. Box 1734 St. John's, Newfoundland A1C 5P5	**SPONSOR**	Environment Canada
		SCIENTIFIC AUTHORITY	W.J. Meades Environment Canada Nfld Forest Research Centre Building 304, Pleasantville St. John's, Newfoundland A1C 5X8 Tele.: (709) 772-4806

OBJECTIVE

To determine the availability of data suitable for calibration of the FORCYTE-11 growth model for selected balsam fir forest types in Nfld; to acquire the necessary data not currently available; and to conduct test runs of the model.

DESCRIPTION

For the calibration, specific parameters, as described in the User's Manual for FORCYTE-11, must be defined for the tree species and nutrients to be simulated. Pertinent scientific literature will be reviewed in the context of potential application to the FORCYTE model. Following this initial investigation the following will be done:

- Design a field sampling procedure that will provide empirical data not available from existing sources.
- Conduct this sampling to incorporate at least three site qualities and fire successional stages of stand development of balsam fir forest types following commercial cutting.
- Undertake field studies to collect baseline data specified in the above User's Manual.
- Undertake chemical and physical analysis of the various parameters.
- Test run the calibrated model.
- Prepare a final report documenting the methodology, sampling procedure and completed input data file for FORCYTE-11.

FUNDING

FISCAL YEAR	SPONSOR	IN-HOUSE		CUMULATIVE TOTAL
1983-84	$25,500	$ 1,000		$ 26,500
1984-85	$50,000	$ 3,000		$ 79,500
1985-86	$41,000	-		$120,500

REPORTS

Northland Associates Limited "A Review of Existing Data Sources for Calibration of the FORCYTE-10 Growth Simulation Model to Balsam Fir in Western Newfoundland," May 1984, St. John's, Newfoundland, ENFOR Project P-264.

STATUS AND COMMENT

PROJECT DATA SHEET #	442	**PROGRAM IDENTIFICATION**	4.3.2.1 Environmental Effects/ Forestry-Silvicultural and Harvest Impacts
TITLE	Study of the Effects of Artificially Produced Acid Rain on the Symbiosis of Mycorrhizal and Biomass Production	**DURATION**	August 1983 - March 1986
CONTRACT #	KH303-3-C-004(OSD83-00063) P-284	**COST**	$274,620
		SPONSOR	Environment Canada
CONTRACTOR	Université Laval Dépt. Aménagement et Sylviculture Faculté de Foresterie et de Géodésie Cité Universitaire Ste-Foy, Québec G1K 7P4	**SCIENTIFIC AUTHORITY**	G. Robitaille Laurentian Forest Research Centre Canadian Forest Service 1080 Route du Vallon Ste-Foy, Québec G1V 4C7 Tele.:
PRINCIPAL INVESTIGATOR	J.A. Fortin		

OBJECTIVE

DESCRIPTION

To measure, in the Montmorency forest, the effect of an increase in the acid level (HS04 and HNO) on the decomposition of wood samples, the levels of N,P,K,S,Ca, Mg, Mn and Al in the soil and ectomycorrhizae, grown in the laboratory.

To determine the influence of pH and the concentrations of Fe, Mn and Al on the development of ectomycorrhizal fungi in the laboratory.

To determine, in the laboratory, the influence of pH and the concentrations of Fe, Mn and Al on the absorption of phosphorus, potassium, calcium and magnesium by naturally occurring mycorrhizae obtained from the Montmorency forest.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-86	$274,620			$274,620

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 443		**PROGRAM IDENTIFICATION**	4.3.2.1 Environmental Effects/ Forestry - Silvicultural and Harvest Impacts
TITLE	Refinement, Evaluation and Testing of Forcyte Simulation Model	**DURATION**	June 1983 - February 1985
CONTRACT #	KH415-3-0312(OSU83-00065) P-285	**COST**	$540,405
CONTRACTOR	University of British Columbia 2975 Wesbrook Mall Vancouver, British Columbia V6T 1W5	**SPONSOR**	Environment Canada
PRINCIPAL INVESTIGATOR	J.P. Kimmins	**SCIENTIFIC AUTHORITY**	L. Chatarpaul Canadian Forestry Service Petawawa National Forest Institute Chalk River, Ontario K0J 1J0 Tele.: (613) 589-2880

OBJECTIVE

To refine, evaluate and test FORCYTE simulation models by using newly acquired data and information to facilitate its use as a widely applicable operational tool for predicting the consequences of intensive forestry.

DESCRIPTION

FORCYTE is an ecosystem-based forest management simulator designed to predict the consequences of intensive forestry (biomass harvest, for example) on site quality and yield as energy efficiencies and cost/benefit ratios. Developed under the ENFOR program through a series of contracts to Dr. J.P. Kimmis, U.B.C., starting in 1978, the model has passed through thirteen stages of development, the tenth and eleventh of which are operational and are being tested. the final two versions of the model will be completed soon.

FORCYTE-10 is now in use/under evaluation/under consideration at 10 locations in 9 countries. The final changes that we intend to make on the model have now been made, and the time has come to undertake, or assist in, its evaluation. This activity will continue through the contract period, making adjustments to the model as seems appropriate. FORCYTE-11 has been developed. This is an intermediate stage between versions 10 and 12 that includes many of the improvements planned originally for version 12, but which only permits simulation of one tree species and one nutrient at a time, and which does not include 12's detailed treatment of the water-regulation of growth.

FORCYTE-12, which has been the subject of conceptual modelling since 1980, will be completed and have had some preliminary evaluation before the start of the 1983 contract year, but, because of its size and complexity, it will be necessary to conduct sensitivity and performance tests and prepare to undertake validation tests.

Development of a detailed users manual, a very large task, would occupy a significant part of the contract period. FORCYTE-13 (Regional-FORCYTE) will have been developed in preliminary form, but it will require a further year's work to set up the model for a demonstration run in conjunction with some forest company or Government forest agency. A user's manual will also have to be prepared. In summary, in order to bring FORCYTE-12 and -13 to an operational condition (as FORCYTE-10 now is), further work will be required.

Accompanying the need for refinement, evaluation and testing of models 12 and 13, calibration of FORCYTE 10/11 in other areas in Canada is required. In Canada the model is only applicable to Douglas fir on Canada's west coast where it was calibrated. For wider application, it must now be calibrated and tested on other tree species and ecosystems before its full potential can be realized. This work is also crucial to achieving ENFOR's goals in assessing the environmental impact of using biomass for energy.

It is therefore intended to let two major contracts in order to produce fully operational versions of the model. One (ENFOR P-286, the subject of a separate contract) which calls for the University of Toronto, working in conjunction with Dr. J.P. Kimmins, U.B.C., to modify, calibrate and apply FORCYTE to predict the consequences of using biomass for energy in Central Canada. This contract is to continue work on refinement, evaluation and testing of FORCYTE and to improve the associated user manuals.

CONTINUED

FUNDING

FISCAL YEAR	SPONSOR	IN-HOUSE		CUMULATIVE TOTAL
1979-80	$ 50,803	$ 5,000		$ 50,000
1980-81	$ 68,808			$119,611
1981-82	$168,200			$287,811
1982-83	$162,097			$454,908
1983-84	$ 48,000			$502,908
1984-85	$ 37,600			$540,405

REPORTS

KIMMINS J.P. and SCOULLAR K.A., "FORCYTE-10. A user's Manual (second approximation)," ENFOR report, (1983).

KIMMINS J.P., SCOULLAR K.A., FELLER M.C., CHATARPAUL L. and TSZE K.M., "Simulation of Potential Long Term Effects of Intensive Forest Management using FORCYTE-10," Soc. Am. For. Proc. (in press)

STATUS AND COMMENT

Continuation of P-71, P-187

84/12/06

PROJECT DATA SHEET # 444

TITLE The Calibrations of FORCYTE simulation model for application to Central Canada

CONTRACT # KH415-3-0256(OSU83-00114)
P-286 ENFOR

CONTRACTOR University of Toronto
Simcoe Hall, Room 1335
Toronto, Ontario
M5S 1A1

PRINCIPAL INVESTIGATOR T.J. Carlton

PROGRAM IDENTIFICATION 4.3.2.1
Environmental Effects/
Forestry - Silvicultural and Harvest Impacts

DURATION August 1983 - March 1985

COST $169,342

SPONSOR Environment Canada

SCIENTIFIC AUTHORITY L. Chatarpaul
Project Leader
Petawawa National Forestry Institute
Department of Environment
Chalk River, Ontario
KOJ 1JO
Tele.: (613) 589-2880

OBJECTIVE

To modify, calibrate and apply the FORCYTE simulation model to predict the consequences of using biomass for energy in central Canada.

DESCRIPTION

1983/84

1. Set up the appropriate version of FORCYTE model at the University of Toronto computers and make a series of diagnostic runs, making adjustments as required.
2. Initiate changes in the model by replacing data pertaining to Douglas fir with empirical Black spruce data.
3. Carry out a survey for suitable experimental sites and initiate, on a range of age and site classes, studies to gather field data according to the User's Manual (in consultation with Dr. J.P. Kimmins).
4. Initiate laboratory processing of tissue and soil samples in order to obtain the required biomass and chemical information.
5. Begin to examine FORCYTE programs for possible re-structuring to suit micro-computers.
6. Examine the possibility of calibrating a deciduous version of the model with available data for hybrid poplar or similar species.

1984/85

1. Complete changes in the model to facilitate simulation of Black spruce stands in the Boreal.
2. Complete field data gathering and laboratory analyses.
3. Carry out calibration procedures, incorporating newly acquired field data.
4. Produce simulated runs for Black spruce and attempt to verify outputs of simulated management scenarios.
5. Complete the investigation into the re-programming of FORCYTE to be operational on a micro-computer.
6. Complete work on calibrating FORCYTE for hybrid poplar or similar species.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1983-84 1984-85	$ 61,740 $107,602			$ 61,740 $169,342

REPORTS

CONTINUED

STATUS AND COMMENT

PROJECT DATA SHEET # 447		**PROGRAM IDENTIFICATION**	4.3.2.1 Environmental Effects/ Forestry-Silvicultural and Harvest Impacts
TITLE	Study of the Impact of Intensive Forestry as Denitrification Kinetics in Forest Soils	**DURATION**	July 1983 - December 1984
CONTRACT #	KH415-3-0462(OSU83-00085) P-287	**COST**	$44,724
CONTRACTOR	University of Windsor Windsor, Ontario N9B 3P4	**SPONSOR**	Environment Canada
PRINCIPAL INVESTIGATOR	D.J. McKenney	**SCIENTIFIC AUTHORITY**	L. Chatarpaul Petawawa National Forestry Institute Canadian Forestry Service Chalk River, Ontario K0J 1J0

OBJECTIVE

To estimate losses of nitrogen from forest soils via denitrification in order to facilitate the calibration of the FORCYTE simulation model to predict the consequences of using biomass for energy in Central Canada.

DESCRIPTION

A. Field studies: A number of sample and comparative control sites will be selected to represent a range of site and age classes and in conjunction with Dr. Terry Carlton of the University of Toronto. Vertical N flux will be measured using the soil cover method. Samples of the enclosed air will be withdrawn periodically at 10 minute intervals over periods of about 1 hour after placement of the soil cover. Corresponding soil samples will be collected, NO^-, and NO^-extracted and stored. Analyses will be performed in the laboratory as soon as possible.

B. Laboratory studies: Soil samples representing the kinds of soil affected by forest management the practices under investigation will be taken periodically during the summer 1983 to the fall 1984. These samples, contained in thermostated tubes, will be made anaerobic or partially anaerobic by a steady flow of inert gas or inert gas, oxygen mixtures. Briefly, NO and N produced in the soil will be monitored continuously in the outlet gas stream. Net production rates of these gases can then be obtained under short-term steady state conditions. Over a wide range of carrier gas flow rates, production rates of NO and N are balanced by removal rates. Production rates of Ncan be estimated by difference.
Soil concentrations of NO^-,, NO^- H and soil-pH will also be measured as a function of time.

Analyses are carried out as follows:

- Nitrous oxide is measured by gas chromatography using a Perkin-Elmer model 3920B with ^{63}Ni electron capture detector.
- The NO is measured using a Columbia Scientific Industries NO/NONOx chemiluminescent analyzer, model 1600
- The NOis reduced to NO which is then analyzed using the NO/NONOx analyser.
- The NO^-, is analyzed by either specific ion electrode or as for NO^-
- Moisture content and pH are determined by standard methods.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84 1984-85	$21,672 $23,052			$21,672 $44,724

REPORTS

CONTINUED

STATUS AND COMMENT

SILVICULTURE

PROJECT DATA SHEET # 107

TITLE Nitrogen-fixing & Mycorrhizal Symbioses in Forests to Increase Biomass Production & Maintain Soil Fertility

CONTRACT # KL011-9-0007
(OSO79-47) P78, P198

CONTRACTOR Université Laval
Faculté Forestière
Ste-Foy, Québec
G1K 7P4

PRINCIPAL INVESTIGATOR M. Lalonde

PROGRAM IDENTIFICATION 4.3.4
Silviculture

DURATION April 1979-March 1984

COST $351,270

SPONSOR Environment Canada

SCIENTIFIC AUTHORITY L. Chatarpaul
Canadian Forestry Service
Petawawa National Forestry Institute
Environment Canada
Chalk River, Ont. KOJ 1JO

OBJECTIVE

To find ways of increasing productivity and maintaining soil fertility of intensive forestry systems grown to produce biomass using nitrogen-fixing species to reduce dependence on fertilizers that are costly in terms of dollars and energy.

DESCRIPTION

1. Prepare a report summarizing available information of N-fixation in forests, its potential as a management tool to increase yield of biomass and maintain soil fertility and need for further research.
2. Establish experiments to examine effects of N-fixing symbioses on yield and soil fertility and, to study the mechanisms involved.
3. Select superior N-fixing genotypes.
4. Examine nitrogen pathway.
5. Attempt to control and produce the Alder endophyte (Frankia).
6. Search for mycorrhizae common to Alder and other tree species to facilitate nitrogen transfer from one species to another.

FUNDING

FISCAL YEAR	SPONSOR	IN-HOUSE		CUMULATIVE TOTAL
1979-80	$ 39,814			$ 39,814
1980-81	$ 54,486			$ 94,300
1981-82	$116,840	$ 1,500		$212,640
1982-83	$133,330	$ 3,000		$348,970
1983-84		$ 2,000		$351,270

REPORTS

FORTIN J.A., CHATARPAUL L., and CARLISLE A., 1984, "The Role of Nitrogen Fixation in Intensive Forestry. Part I: Principles, Practice and Potential," CFS Inf. Rep. PI-X-28.

FORTIN J.A., CHATARPAUL L., and CARLISLE A., 1984, "The Role of Nitrogen Fixation in Intensive Forestry. Part II: Research Carried Out at Laval University, Quebec on nitrogen-fixing actinorrhizal trees and shrubs," CFS inf. Rep. PI-X-29.

NORMAND P., LALONDE M., FORTIN J.A., and CHATARPAUL L., 1984, "Isolation Characterization and Evaluation of Frankia Strains," CFS Inf. Rep. PI-X-30.

CONTINUED

STATUS AND COMMENT

Sites selected, plants raised for planting in 1980. Nitrogen pathway and screening experiment in progress. Common mycorrhizae (*Alnus* and *Picea*) located (*Paxillus*). *Frankia* production under control.

Interim report dated May 1981 covers work performed to July 1980 but does not attempt to synthesize the research results. Contract complete. In-house work continuing.

84/11/29

PROJECT DATA SHEET # 290

TITLE Boreal Energy Plantation R & D

CONTRACT #
KH205-1-125 (OSC 82-15)
P-172
KH205-3-0018(OSC83-00092)
KH205-3-0060(OSC83-00304)

CONTRACTOR
1. W.C. Wilton, St. John's, Nfld
2. A. Dyer, St. John's, Nfld
3. Highlands Contracting, Gander
4. R. Mednis, Memorial Univ. St. John's
5. H. McCaughey, Queen's Univ Kingston, Nfld
6. A. West, St. John's

PROGRAM IDENTIFICATION 4.3.4 Silviculture

DURATION April 1981 - March 1986

COST $377,939

SPONSOR Environment Canada

SCIENTIFIC AUTHORITY
A. Robertson
Nfld. Forest Research Center
Canadian Forestry Service
Box 6028
St. John's, Nfld.
A1C 5X8

OBJECTIVE

To develop the methodology and test the feasibility of short-rotation energy plantations based on willow coppice in boreal forest regions.

DESCRIPTION

Over 200 willow clones have been acquired from Europe and North America and are being mass propagated and screened for energy plantation trials.

A pilot study of potential land use and economic assessment of willow energy plantations on the Avalon Peninsula, eastern Newfoundland was carried out.

Several sites have been developed for trial energy plantations in central and eastern Newfoundland. At least two more are planned for western Newfoundland.

Methodology and instrumentation to study the energy balance of energy plantations, to aid in the clone/silt matching, is being developed and should be operational for the 1985-86 season.

Biogeographical studies of willow species in Europe and eastern North America have been conducted to provide a detailed understanding of their ecological amplitude and adaptability to cultivation.

An entomological study of willow pests has also been carried out.

FUNDING

FISCAL YEAR	SPONSOR	IN-HOUSE		CUMULATIVE TOTAL
1981-82		$11,700		$ 11,700
1982-83	$ 25,610	$ 1,500		$38,810
1983-84	$ 84,670	$ 3,000		$126,480
1984-85	$111,459	$10,000		$247,939
1985-86	$130,000			$377,939

REPORTS

ROBERTSON A., "Boreal Forestry: The Amphi-Atlantic connection," Bioenergy Seminar, University of Minnesota, St. Paul, Minn., 1984.

ROBERTSON A., "Boreal Agroforestry in Europe and its relation to Newfoundland," Seminar Series, Faculty of Forestry, Univ. Toronto, 1984.

ROBERTSON A., "Boreal Energy Plantation R&D in Newfoundland," Proc. 6th International Workshop on Forestry Regeneration at High Latitudes, Edmunston, New Brunswick, 1984.

ROBERTSON A., "Boreal Agroforestry: Its Relationship to Peatlands," Proc. Symposium International Peat Society, St. John's, 1983

ROBERTSON A., "Willow Plantations in Agroforestry," SPAN 27(1):32-34, 1984.

CONTINUED

STATUS AND COMMENT

This project will continue with funding from ENFOR.

84/12/06

PROJECT DATA SHEET # 294

TITLE Transfer of Nitrogen Fixing Capability from Alder (*Alnus*) to birch (*Betula*)

CONTRACT # KH415-1-1252 (OSS81-00210)
P-232

CONTRACTOR University of Laval
Sainte-Foy, Québec
G1K 7P4

PRINCIPAL INVESTIGATOR M. Lalonde

PROGRAM IDENTIFICATION 4.3.4
Silviculture

DURATION February 1982 - March 1984

COST $56,701

SPONSOR Environment Canada

SCIENTIFIC AUTHORITY L. Chatarpaul
Environment Canada
Canadian Forestry Service
Chalk River, Ontario
K0J 1J0
Tele.: (613) 589-2880

OBJECTIVE

To provide a basis for development of a nitrogen-fixing *Betula/Frankia* symbiosis to increase fibre yield and maintain nitrogen levels of forest soils by selecting, culturing, and fusing *Betula* and *Alnus* protoplasts as a precursor to overcoming the infectivity barrier between *Betula* and *Frankia*.

DESCRIPTION

1. Select and grow in the greenhouse germ plasm of different *Alnus* species, e.g. *Alnus crispa*, *A. rugosa*, *A. glutinosa*, *A. rubra* and *A.* cordata.
2. Select and grow in the greenhouse germ plasm of *Betula papyrifera*.
3. Isolate the protoplasts from *Alnus* and *Betula* types.
4. Cultivate *in vitro* the isolated protoplasts of *Alnus* and *Betula*.
5. Select different protoplast marker mutants, chlorophyll deficient mutants, antibiotic resistant mutants, metabolic mutants, infectivity mutants of *Frankia*.
6. Attempt to produce hybrids by the polyethylene glycol-induced fusion of *Alnus* protoplasts with *Betula* protoplasts.
7. Screen and recover fused protoplasts.
8. Cultivate *in vitro* selected somatic hybrids of *Alnus* and *Betula*.

FUNDING

FISCAL YEAR	SPONSOR	IN-HOUSE		CUMULATIVE TOTAL
1982-83	$25,845	$ 6,300		$32,145
1983-84	$24,556			$56,701

REPORTS

TREMBLAY F.M., and LALONDE M., "Tissue Culture of Nitrogen-fixing *Alnus* and *Betula*", in Fifth Bioenergy Proceedings, March 25-28, Ottawa, Ontario, 1984.

TREMBLAY F.M., and LALONDE M., "Requirements for in vitro propagation of seven nitrogen fixing *Alnus* species", Plant Cell tissue Org. Cult. (in press), 1984.

TREMBLAY F.M., NESME X., and LALONDE M., "Selection of Micropropagation of Nodulating and non-nodulating clones of *Alnus crispa* (Ait.) Pursh", Plant Soil. (in press).

STATUS AND COMMENT

Phase 1 of work complete. Work is continuing at Laval University.

84/12/06

PROJECT DATA SHEET # 304		**PROGRAM IDENTIFICATION**	4.3.4 Silviculture
TITLE	Land Application of an Industrial Sludge to Hybrid Poplar Plantations - A Lysimeter Study	**DURATION**	October 1982 - March 1985
		COST	$25,100
CONTRACT #	KN107-2-4425 (05S82-00108) P-248	**SPONSOR**	Environment Canada
CONTRACTOR	Du Pont Canada Inc. Maitland Works P.O. Box 611 Maitland, Ontario KOE 1P0	**SCIENTIFIC AUTHORITY**	Mel Webber Residue Management Section Environmental Protection Service 867 Lakeshore Road Burlington, Ontario L7R 4A6

OBJECTIVE

1. Determining the nitrogen uptake capacity of hybrid poplars grown on soil taken from the site and amended with sludge.
2. Determining the growth response and nutrient and heavy metal uptake by poplars grown on the sludge treated soils.
3. Determing the nutrient and heavy metal concentrations in leachates collected from the sludge amended soils.
4. Determining the effect on soil structure and permeability of high sodium concentrations in the sludge.

DESCRIPTION

Experimental Design: No. of lysimeters - 44, No. of replicates - 4, No. of treatments - 11
Treatments: - Nitrogen fertilizer applied at 125, 250, 500 kg N/ha.yr
- Sludge; surface applied at 125, 250, 500, 1000 kg N/ha.yr
- Sludge; incorporated in 0-15 cm soil at 125, 250, 500, 1000 kg N/ha.yr
Phosphorus and potassium fertilization - 100 kg P/ha.yr and 250 kg K/ha.yr supplied to all treatments.
Soil - one type: Sludge - one type; dewatered to 10% solids: Hybrid Poplar - one species; four cuttings per lysimeter, supplied by the Ministry of Natural Resources
Plant Response and Analysis: Measurements of plant response include total plant height and girth at a given height. One plant from each lysimeter is harvested in early August of each year. Leaf and stem weight is measured prior to preparation for analysis. Leaves and stems are analyzed for N, P, K, Ca, Mg, Na, Cd, Zn, Cu, Ni, Pb, Cr and Mo.
Soil Sampling and Analysis: Samples of 0-15 cm soil taken from each lysimeter prior to initiating the experiment and during September of subsequent years are analyzed for total N, Cd, Zn, Cu, Ni, Cr, Mo, cation exchange capacity, exchangeable Ca, Mg, K and Na.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR	IN-HOUSE	CUMULATIVE TOTAL
1982-83	$ 5,000			$ 5,000
1983-84	$11,850		$1,000	$17,850
1984-85	$ 7,250			$25,100

REPORTS

Reports for the periods June to December 1982 and January to March 1983 are completed.

CONTINUED

STATUS AND COMMENT

The study is on-going with a planned completion date of November 1984.
84/12/06

PROJECT DATA SHEET #	403
TITLE	Tissue Culture and Micro-Propagation for Forest BiomassProduction
CONTRACT #	31926-3-5045 (OSR83-00127)
CONTRACTOR	Frank Maine Consulting Ltd 71 Sherwood Drive Guelph, Ontario N1E 6E6
PRINCIPAL INVESTIGATOR	Frank Maine
PROGRAM IDENTIFICATION	4.3.4 Silviculture
DURATION	March 1984 - September 1984
COST	$48,000
SPONSOR	Bioenergy Program National Research Council
SCIENTIFIC AUTHORITY	S. Hasnain Division of Energy R&D National Research Council Building R-105, Rm. 138 Ottawa, Ontario K1A OR6 Tele: (613) 993-1342

OBJECTIVE

To carry out a feasibility study on the prospects for the application of biotechnology in Canada (a) for the large scale production of trees, via micropropagation, for energy, fuels and fiber and (b) for the production (through genetic manipulation) of new varieties of trees having superior qualities such as higher productivity, disease resistance and tolerance to herbicides.

DESCRIPTION

Task One: A comprehensive review of the literature on developments in micropropagation of forest trees (softwoods & hardwoods) dealing with issues such as methods for producing suspension cultures and techniques for embryogenesis and organogenisis from haploid and diploid suspension cultures. Methods for regeneration from tissue slices such as meristem or leaf sections will also be addressed. In addition, the study will cover developments in plant genetic manipulation such as cell fusion (inter and intraspecific and intergeneric) and recombinant DNA methods and vectors. Concerning cell fusion research, particular attention will be given to the successful regeneration of plant from fused cells. The literature will also be reviewed on the application of conventional mutation inducement and selection from tissue cultures of plants. Lastly, the literature will be reviewed for work done on the establishment of biochemical markers for the selection of desirable traits in tree tissue cultures and/or markers should be identified as likely candidates for screening tests. Where there is a scarcity of information on forest tree species, examples from horticulture and agriculture will be used if there is potential application to forest trees.
Task Two: Along with the review, an annotated bibliography will be included.
Task Three: The contractor will define the terms of reference for a proposed federal program for the support of R&D on tree micropropagation and genetic manipulation with the expectation that the work will lead to the application of micropropagation for the large scale production of planting stock for reforestation and that genetic manipulation will lead to the development of new improved varieties of trees. Along with the definition of the work program, the contractor will identify the appropriate performers in government, universities, industry and institutes who would be capable of carrying out the work. the contractor will identify the range of experience of each prospective performer, the available talent and the existing facilities.
Task Four: The contractor will identify a number of milestones relating to the expected successes. The time frame will include both near term objectives and also long range objectives such as the use of genetic manipulation for the transfer of nitrogen fixing capability.
Task Five: In relation to the time scale and milestone definition, the contractor will attempt to provide an estimate of the benefit/cost ratio of following this line of development.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1984-85	$48,000			$48,000

CONTINUED

REPORTS

Final reports, including a literature review and recommendation for a Canadian program are being published and will be available through CISTI

STATUS AND COMMENT

These studies and other investigations show that there is considerable potential for increasing forest biomass productivity using tissue culture methods for clonal propagation and for forest tree improvement. To fully develop this potential an expanded Canadian R&D effort is required. One aspect of the technology, the mass production of plantlets from superior full-sib seed using the juvenile tissue culture methods, could be transferred to commercial application in a relatively short time, after the appropriate demonstration. Large scale demonstrations in the U.S., New Zealand, Sweden and France are already in place

PROJECT DATA SHEET # 405

TITLE	Forest Improvement: Tissue Culture Propagation of Conifers for Reforestation
CONTRACT #	Strategic Grant
CONTRACTOR	University of Calgary Department of Biology Calgary, Alberta T2N 1N4
PRINCIPAL INVESTIGATOR	T.A. Thorpe D.I. Dunstan
PROGRAM IDENTIFICATION	4.3.4 Silviculture
DURATION	November 1981 - November 1984
COST	$132,330
SPONSOR	Natural Sciences and Engineering Research Council Canada

OBJECTIVE

(1) To develop protocols for the propagation of conifers from seedlings of seed of selected elite trees (2) To carry out empirical studies using buds (dormant and non-dormant) in studies on development and multiplication for plantlet production. (3) To reduce aberrant shoots, which are often produced under in vitro conditions, to increase yield of usable shoots for rooting. (4) To carry out detailed rooting studies to maximize the number of plantlets formed. (5) To carry out studies on hardening of plantlets to increase field survival. Thus the overall objective of this work is the development of protocols for the mass clonal propagation of selected conifer species for reforestation in Canada's forest. It is the aim of the Kelowna Nurseries to be able to supply large quantities of tissue-culture derived plantlets on contract for use along side the presently produced containerized forestry seedling stock for reforestation.

DESCRIPTION

Using seed, seedlings, and vegetative buds of the following conifers - western red cedar, white, black and Sitka spruce, Douglas fir, lodgepole pine, and western others, four stages in the process can be recognized (Thorpe, 1977). These are (1) bud initiation on the explant, (2) shoot development and multiplication, (3) rooting of developed shoots and, (4) preparation of the plantlets for planting out.

(1) Aseptically germinated seed will be used as explants. Such explants include cotyledons, hypocotyls and epicotyls, depending on the species. Research to date has shown that placing such explants in culture on a defined medium such as Schenk and Hildebrandt's (1972) in the presence of a cytokinin, and sometimes an auxin as well, will lead to bud induction in solid cultures (Thorpe, 1977; Cheng, 1978). The best explant, the age of the explant, the media additives, the length of time in initial culture in the presence of phytohormones, the photoperiod, intensity of illumination, etc., must all be worked out empirically for the different species, and even the different ecotype to produce the maximum number of buds.

(2) The bud development or multiplication stage often occurs best in the absence of any phytohormone, often with reduced levels of sucrose, and a low level of charcoal in the medium, in light. Again the optimum condition have to be worked out empirically. Although Coleman and Thorpe (1977) obtained success with vegetative buds of western red cedar, the most definitive studies have been by von Arnold and Eriksson (1979). Using resting buds and needles from newly flushed buds of Norway spruce, they were able to obtain good adventitious bud formation by temperature, cytokinin manipulations on a defined medium. Thes approaches will be used in manipulating maximum adventitious bud formation.

(3) Rooting of the developed buds is perhaps the most difficult phase of plantlet production. The best rooting obtained to date is 80% by Horgan and Aitken (1981) in radiata pine. Most species root less than 50%. In general some rooting will occur in the presence of auxin, usually indole butyric acid, on stregth mineral salts. Preparation of the shoots for rooting is very important. Thermoperiod has been shown to be important in rooting (Cheng and Voqui, 1977). All these factors will be taken into account. Attempts will also be made to achieve rooting under non-sterile conditions in the greenhouse in vermiculite or other rooting media to reduce costs and handling.

(4) Hardening of plantlets will involve traditional horticultural approaches such as misting, sequential increase in light intensity, etc. Loss at this stage varies with the species.

(5) Aberrant shoots are often formed in culture. These are dark green, clear succulent shoots (Aitken et al., 1981). These are slow to elongate and do not root readily. Free water in the cultures and very high humidity seem to contribute to the problem. A thorough investigation of this problem will be undertaken to increase the maximum number of rootable shoots.

(6) Problems involved in the scale up of plantlet production for mass propagation will also be examined, with each species as the complete protocol is worked out. In addition, initial evaluation of tissue-culture derived plantlets in the field will be made.

CONTINUED

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1981-82 1982-83 1983-84	$40,000 $44,800 $47,530			$ 40,000 $ 84,800 $132,330

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET #	410	**PROGRAM IDENTIFICATION**	4.3.4 Silviculture
TITLE	Tree Improvement: anatomical, physiological and biochemical approaches to obtaining early and enhanced seed production in conifers	**DURATION**	November 1983 - November 1986
		COST	$210,000
CONTRACT #	Strategic Grant	**SPONSOR**	Natural Sciences and Engineering Research Council of Canada
CONTRACTOR	University of Calgary Department of Biology Calgary, Alberta T2N 1N4		
PRINCIPAL INVESTIGATOR	R.P. Pharis Biology, U. of Calgary J.N. Owens Biology, U. of Victoria		

OBJECTIVE

1) To determine more precisely effective treatment dosages, application techniques, possible use of gibberellin synergists (chemical)and synergistic cultural treatments to promote differentiation of pollen-and seed-cone buds on Pinaceae family conifers. The end result would be a cost-and time-effective promotion of flowering for breeding and seed production purposes.
2) Examine the factors that control sexuality (e.g. male vs female) of conifer cone, utilizing both Cupressaceae and Pinaceae family species. The end result would be to manipulate the sex to (a) obtain early pollen-cone bud production in controlled pollinations in seed orchards, and (b) to obtain early seed-cone bud production and to increase the number of seed-cone buds to the maximum that can be supported by seedlings or propagules in the seed production orchard.
3) Examine the factors that determine whether a bud will be "latent", as opposed to differentiating into a cone buds in poor flowering years when the latent bud category normally makes up a high proportion of lateral buds.
4) Determine more precisely, using histochemical and ultrastructural techniques, the earliest stages of cone-bud differentiation so that timing of treatment can be more efficient and cost effective.
5) Obtain a better understanding of how endogenous hormones (gibberellins, cytokinins and auxins) and the exogenous gibberellins (GA4/7) act and interact when they induce cone bud initiation or differentiation (e.g. as diverters of photosynthate or as direct morphogenic agents?).

Initiate new (and continue ongoing) projects on conifers located in private and B.C. Forest Service (Res. Branch) seed orchards (field, plastic house, controlled-environment chamber), in collaboration with Drs. S. Ross and J. Webber, B.C. Forest Service (Res. Branch) and other collaborators (e.g. in Canada and abroad). These will include experiments on the following: (i) labeled tracers, (ii) metabolism of [H] GA7 on Douglas fir or western hemlock (or other appropriate species) under circumstances where flowering efficacy can be related to level of precursor (e.g. precursor active per se) or metabolite (e.g. product of precursor) active, (iii) examine of endogenous hormones (gibberellins/cytokinins/indole-3-acetic acid) and hormone metabolism (gibberellins) under circumstances where sex of the cone bud can be manipulated by environmental treatment (photoperiod/temperature) or by position within the crown or on the branch, (iv) begin an assessment of the usefulness of gibberellin synergists (isourea derivatives) in promotion of flowering in Pinaceae family conifers, (v) begin experiments to study specific timing of treatment effects as they influence bud differentiation in species for which material is available, (vi) begin experiments to study specific timing of treatment effects as they influence bud differentiation in species for which material is available, (vi) begin experiment to clarify or distinguish the effects of stress (e.g. water stress) and gibberellins on bud and shoot morphogenesis.

Harvest and begin laboratory analysis of tissue, with interim results being accomplished in time to initiate new or follow-up experiments in spring, 1985.

Initiate new and follow-up experiments, as necessary, for confirmation or continued progress toward elaborating (i-vi) above. New studies will include: (a) analyses (primary histochemical) of vegetative and reproductive buds to identify unknown compounds which accumulate in potential vegetative and latent buds but not potential reproductive buds during early development; (b) ultrastructural studies to determine origin and localization of the compounds in (a) above.

Based on assessment of results to date, continue follow-up experiments, emphasizing promising leads. Attempt to test, in field (defined broadly to include plastic house seed orchards and/or controlled environment chambers), all promising treatments under circumstances where "cost-effectiveness" of treatment can be assessed (e.g. cost per "genetically superior" seed produced).

CONTINUED

DESCRIPTION

Long-Term: to ensure that genetic improvement of commercially important forest tree species in Canada will not be limited by an inability to obtain early flowering for breeding purposes, and that at least enough seed therefrom will be available for progeny testing, and to ensure that seed production in orchards (field or plastic house) of genetically superior propagules is no longer limited by an inability to produce regular and sufficient amounts for reforestation.

Short-term:

1) Through a melding of applied and basic research, determine the optimum timing and mode of application of cultural treatments and hormone (GA4/7/auxin) to produce a cost-effective treatment in seed orchards.
2) An examination of the mechanisms controlling sexuality (male vs. Female) in conifer cone buds, with the ultimate aim of being able to control sexual differentiation for breeding and seed orchard purposes.
3) Factors controlling the formation of latent buds. Latent buds make up the major bud category in many conifers (such as Douglas fir) in a poor flowering year. Latent buds appear to be potential cone buds (mainly pollen cone buds) whose development has been arrested. A better understanding of the latent bud, and the factors controlling its formation, may allow manipulation of these bud types into cone buds in what woul otherwise become a "poor flowering" year.
4) How do hormones, exogenously applied or endogenous, act to influence cone-bud initiation/differentiation?

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84 1984-85 1985-86	$ 70,000 $ 70,000 $ 70,000			$ 70,000 $140,000 $210,000

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET #	413	**PROGRAM IDENTIFICATION**	4.3.4 Silviculture
TITLE	Drought Tolerance and Physiological Mechanisms of Resistance in Coniferous Planting Stock	**DURATION**	November 1983 - November 1986
		COST	$90,000
CONTRACT #	Strategic Group	**SPONSOR**	Natural Sciences and Engineering Research Council of Canada
CONTRACTOR	University of Waterloo Waterloo, Ontario N2L 3G1		
PRINCIPAL INVESTIGATOR	E.B. Dumbroff		

OBJECTIVE

To provide the biophysical and biochemical information necessary to develop practical hardening procedures that will induce the physiological states that will most favor rapid seedling establishment and reduce seedling loses induced by the short but frequent "summer droughts" common to many outplanting sites.

DESCRIPTION

During the first phase of the work, state-of-the-art analytical methods will be used to define the mechanisms by which the seedlings adjust to drought stress with major emphasis placed on: (1) the maintenance of turgor as a consequence of osmotic adjustment, (2) the effect of stress on the components of the photosynthetic process and on photosynthetic efficiency, and (3) the importance of endogenous plant growth regulators (e.g. ABA, ethylene, phenolics) in the stress adjustment process. During the second phase of the project, we will investigate the potential for using natural and synthetic inhibitors, dwarfing compounds and ion-loading techniques to induce the biochemical and morphological changes shown during phase one to be most closely associated with drought resistance. When sufficient data has been accumulated, we will also cooperate in the establishment of on-the-ground tests of our principal findings, and we will proceed with the development of a convenient test that can be used to assess the drought tolerance of coniferous seedlings.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1983-84 1984-85 1985-86	$30,000 $30,000 $30,000			$ 30,000 $ 60,000 $ 90,000

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 426		**PROGRAM IDENTIFICATION**	4.3.4 Silviculture
TITLE	Development of Silvicultural Treatments to Maximize Biomass Production in Aspen Stands	**DURATION**	May 1983 - March 1984
		COST	$39,996
CONTRACT #	KH415-3-0056(OSS83-00014) P-257	**SPONSOR**	Environment Canada
CONTRACTOR	Horton Forestry Services Ltd. R.R. 4 Stouffville, Ontario LOH 1LO	**SCIENTIFIC AUTHORITY**	W.M. Stiell Petawawa National Forestry Institute Canadian Forestry Service Chalk River, Ontario KOJ 1JO Tele.:
PRINCIPAL INVESTIGATOR	B.J. Horton		

OBJECTIVE

To maximize biomass yield of natural aspen stands by:

(a) developing, testing and demonstrating silvicultural treatments to favour selected superior clones for major genetic gains through higher quality reproduction.

(b) assessing effects of initial stocking on biomass yield and testing silvicultural treatments to maximize production.

CONTINUED

DESCRIPTION

Aspen in Ontario comprises a very large but scarcely exploited source of wood which cannot be ignored in any serious program of biomass production from the forest. While natural stands of aspen have the potential to increase forest production several fold, they are often characterized by poor stocking, overmaturity or uneconomic species mixtures. The problem is how to remedy these deficiencies by appropriate silvicultural methods. These stands exist, ready made, and managing them for biomass production represents a problem and an opportunity in utilization of the forest resource for energy that is complementary to, and not less significant than hybrid poplar management on agricultural soils.

In the context of forest renewal, aspen regeneration (predominantly from root suckering) is practically omnipresent, occurring to some degree in almost all upland areas subjected to logging or wildfire. Until recently, forest management has emphasized removing it to favour preferred conifers, particularly on planted sites. So there has been little or no interest in improving aspen regeneration experimentally or operationally. However, as ENFOR report P-30(2) outlines, aspen suckering is readily available at no or minimal silvicultural cost, but is very variable in quality and easily manipulated in quantity. It can provide much greater yields than other native species on most upland sites. Moreover, the prospect of increasing aspen utilization in biomass and conventional (pulpwood, plywood, particle board) terms argues in favour of concerted silvicultural testing -- and the proposal would provide an appropriate first effort.

Proposed Approach: Typical stands exist at PNFI, where the study would preferably be carried out for reasons of security, protection and future maintenance by staff. Selection of typical stands will be followed by treatments designed to correct the problems described above, and embodying sampling systems to allow long-term monitoring and study. Specific treatments will be:

(a) In overmature stands, on two sites, clones will be mapped and treatments applied to improve clonal structure of sucker regrowth. In brief, treatments will be designed to promote suckering from superior clones and inhibit it from inferior clones. to our best knowledge, this has never been tested in North America. More specifically, treatments to encourage good clones will be:
   (i) clear cutting
   (ii) clear cutting plus scarification or burning
   (iii) the "root tree" method hypothesized in ENFOR Report P-30(2).

   Poor and mediocre clones will be eliminated by clear cutting and applying herbicides to stumps and existing suckers.

   Ideally, treatments could be applied in early summer on replicated large plots, each with a sizeable surround. In fact, the size and arrangement of plots would depend on size, shape and distribution of clones. Clones must be delineated and classified at time of leafing out when they are most readily differentiated.

(b) Young (20-year) stands of varying stocking levels will be identified and growth as a function of stocking evaluated. Treatments to achieve optimum stocking will be designed and tested. As a result of an unrelated abondoned project, generally suitable young stands are already present in a block format adjoining the older stand area, (a) above. Permanent plots can be established here to assess growth and biomass yield to date in relation to stocking. If necessary, additional spacing and thinning may be applied in some blocks to provide an appropriate range of stocking treatments for further comparison at 5-year intervals to rotation age of 30 to 40 years. Again, the particular plot layout must await a detailed assessment of existing blocks.

   Thus, (a) is designed to test practival methods for significantly improving quality of aspen regeneration, and hence biomass yield; while (b) is designed to determine in a relatively short period the optimum stocking for biomass production vs. conventional uses.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$39,996			$39,996

REPORTS

HORTON, B.J., Horton Forestry Services Ltd., "Silvicultural Treatments to Maximize Biomass Production in Aspen Stands," Stouffville, Ontario, ENFOR Project P-257, Final Report May 1984.

CONTINUED

STATUS AND COMMENT

Project P-257 completed

84/12/06

PROJECT DATA SHEET #	446
TITLE	National Alder Seed Collection
CONTRACT #	P.N.F.I. 83-060 P.N.F.I. 83-061 P.N.F.I. 83-065 P.N.F.I. 83-067 P.N.F.I. 83-092 P.N.F.I. 83-103
CONTRACTOR	R. Le Blanc Reid, Collins Nurseries Ltd D. Pigott J. Middlemiss B. Kelley

PROGRAM IDENTIFICATION	4.3.4 Silviculture
DURATION	April 1983 - March 1984
COST	$21,511
SPONSOR	Environment Canada
SCIENTIFIC AUTHORITY	P. Janas Petawawa National Forestry Institute Chalk River, Ontario K0J 1J0

OBJECTIVE

To provide a base collection of well documented, properly handled, tested and stored alder seed from across Canada for use by researchers in nitrogen fixation and biomass production studies.

CONTINUED

DESCRIPTION

In accordance with the above objective, approximately 450 seedlots comprising single tree and general collections of Alnus crispa, rubra, rugosa, sinuata and tenuifolia were collected from selected forest regions in British Columbia, Alberta, Ontario, New Brunswick, Prince Edward Island and Nova Scotia in autumn 1983. Trees chosen for collection were of above average form and vigour, free of insect or disease infestation and far enough apart in each stand to minimize genetic relatedness. Height, diameter and age of each collected tree were recorded on seed registers.

All seedlots were processed, tested, documented and stored at the National Tree Seed Centre facilities at the Petawawa National Forestry Institute. This seed is now available for use by researchers, and an interim alder seed list has been prepared and distributed to requesting agencies.

P.N.F.I. 83-060

Mr. Ray Le Blanc

To locate and report possible future collection sites for seed of these species in the Maritime provinces (exc. Newfoundland).

1) B.2 Gasp
2) A.3 Eastern Lowlands
3) A.11 Atlantic Uplands

P.N.F.I. 83-061

Reid, Collins Nurseries Limited

To collect cones from superior trees of Alnus rugosa, sinuata and tenuifolia found in high quality stands in the following forest sections:

1) B-17: Aspen Grove
2) B-19a: Lower Foothills
3) SA-2: Interior Subalpine

P.N.F.I. 83-065

Mr. Don Pigott

To collect cones from superior trees of Alnus rubra, sinuata and tenuifolia in high quality stands in the following forest subsections:

1) B.25 - Stikine Plateau
2) M.4 - Montane Transition
3) M.2 - Central Douglas-fir
4) SA.2 - Interior Subalpine
5) CL.1 - Southern Columbia
6) C.2 - Southern Pacific Coast
7) SA.3 - Coastal Subalpine

P.N.F.I. 83-067

Mr. John Middlemiss

To collect cones from superior trees of Alnus rugosa found in high quality stands in the follwing forest sections:

1) L.2 - Upper St. Lawrence
2) L.4c - Middle Ottawa

P.N.F.I. 83-092

Mrs. Bozena Kelley

To perform laboratory seed testing of alder seed collected in the 1984 National Alder Seed Collection. Laboratory tests include:

1) Germinating each seedlot to determine seed viability;
2) Taking moisture contents of all lots;
3) Determining 1000 seed weight for each lot;
4) x-raying seed with low germination to determine causes;
5) measuring seed quantity with an electronic balance.

P.N.F.I. 83-103

Mrs. Bozena Kelley

To perform registration, documentation and electronic filing of seedlots collected in the 1983 National Alder Seed Collection by:

1) Packaging alder lots in appropriate receptacles and attaching seedlot identification cards;
2) Summarizing 1000 seed weight, moisture content, germination and cone counts on computer input forms;
3) Recording provenance and test information on seed register forms;
4) Entering provenance and test data into computer files.

CONTINUED

FUNDING

FISCAL YEAR	SPONSOR	CONTRACT #		CUMULATIVE TOTAL
1983-84	$2,098	P.N.F.I.83-060		$ 2,098
	$5,047	P.N.F.I.83-061		$ 7.145
	$8,500	P.N.F.I.83-065		$15,645
	$ 466	P.N.F.I.83-067		$16,111
	$3,600	P.N.F.I.83-092		$19,711
	$1,800	P.N.F.I.83-103		$21,511

REPORTS

A report covering alder seed collections in 1983 and 1984 will be prepared for early 1985

STATUS AND COMMENT

Collecting will continue in the remainder of Canada during this autumn as part of the second and final year of this program.

84/12/06

BIOMASS PLANTING, HARVESTING AND COLLECTION TECHNOLOGIES

PROJECT DATA SHEET # 195

TITLE	Development of the RECUFOR & application of the RECUFOR rotor to comminution of residues at landings.
CONTRACT #	KL229-1-4203(05581-00095) P-210, P-215
CONTRACTOR	Forest Engineering Research Institute of Canada 143 Place Frontenac Pointe Claire, P.Q. H9R 4Z7
PRINCIPAL INVESTIGATOR	D. Brière
PROGRAM IDENTIFICATION	4.3.5 Biomass Planting, Harvesting and Collection Technologies.
DURATION	July 1981 - March 1985
COST	$1,305,340
SPONSOR	Environment Canada
SCIENTIFIC AUTHORITY	B.J. Sutherland Great Lakes Forest Research Centre 1189 Queen Street Sault-Ste-Marie, Ontario

OBJECTIVE

1. The development of the RECUFOR.
2. Applications of the RECUFOR rotor to the comminution of residues at landings. The RECUFOR concept consists essentially of a powered, 3-foot diameter, cylinder equipped with 3 rows of curved teeth whose main function is to pick up on-the-ground logging residues. These residues are sheared against fixed knives. The purpose of the contract is: (a) to design, fabricate and test a mobile machine incorporating the RECUFOR concept; (b) to augment the comminution process by combining the RECUFOR with a conventional hog or chipper, to prepare the best material for storage, transportation and conversion.

DESCRIPTION

A.

1. To asses the various possible conceptual configurations for the RECUFOR and to select one for development.
2. To develop the design selected under (1) in sufficient detail that it can be efficiently manufactured and to prepare all necessary shop drawings and/or specifications for all components.
3. To manufacture one model of the machine according to the drawings and specifications of (2) above.
4. To execute shop and critical field tests with the machine of (3) above to ensure that it is free of major faults and to correct any such faults.

B.

1. The development of a design combining the RECUFOR with a conventional comminution device. A technical and economic feasibility analysis to be included.
2. Based on the design developed in (B.1), a program is to be proposed for the development and testing of an experimental prototype incorporating the RECUFOR.

FUNDING

FISCAL YEAR	SPONSOR	IN-HOUSE		CUMULATIVE TOTAL
1981-82	$552,121	$ 3,000		$ 552,121
1982-83	$163,910	$ 1,100		$ 719,031
1983-84	$517,700			$1,237,831
1984-85	$ 67,509			$1,305,340

REPORTS

CONTINUED

STATUS AND COMMENT

Final report is expected by December 1984.

84/12/04

PROJECT DATA SHEET # 293

TITLE Design of a Harvester-Chipper-Conveyor-Storage System to Harvest Brushwood using the "Pallari Cutting Principle"

CONTRACT # KH405-2-0053 (0SS82-00081)
P-231

CONTRACTOR
ELMS Design Incorporated
647 Tomahawk Crescent
Ancaster, Ontario
L9G 3N2

PRINCIPAL INVESTIGATOR R.G. Elms

PROGRAM IDENTIFICATION 4.3.5
Biomass Planting, Harvesting and Collection Technologies

DURATION August 1982 - March 1985

COST $492,020

SPONSOR Environment Canada

SCIENTIFIC AUTHORITY
B.J. Sutherland
Great Lakes Forest Research Centre
Canadian Forestry Service
P.O. Box 490
Sault Ste. Marie, Ontario
P6A 5M7
Tele.: (705) 949-9561

OBJECTIVE

1. To design, based on the Pallari cutting principle, a harvesting-chipper-conveyor-storage system to harvest brushwood in Canada.
2. To identify a suitable, commonly available carrier onto which the brush harvester design described in (1) is to be incorporated.
3. To produce engineering detail and assembly drawings.
4. To fabricate a prototype harvester-chipper-conveyor system and mount it on the carrier selected in (2).
5. To field test the prototype brush harvester in representative brushwood conditions located in Ontario.

DESCRIPTION

1. Design of the harvesting-chipper head portion of the system on the Pallari concept using detail and assembly drawings of the Pallari.
   Incorporte a chipping unit into the harvesting head design. A conveyor system to remove the harvested and chipped material will be designed as an integral part of the harvester-chipper unit. Preliminary design work on a storage system.
2. Incorporate the brush harvester onto a carrier.
3. The contractor will provide detail and assembly drawings such that the prototype harvester-chipper-conveyor system may be fabricated by any competent fabricator in Canada. The unit will be designed as a continuously-progressing, swath cutting unit. The equipment must be designed to negotiate moderately rolling terrain.
   Other conditions to be taken into account are soil, soil moisture and drainage, and stand conditions. Surfaces ranging from very even to moderately uneven must be accommodated.

FUNDING

FISCAL YEAR	SPONSOR	IN-HOUSE		CUMULATIVE TOTAL
1982-83	$ 58,220	$ 8,000		$ 67,020
1983-84	$230,000			$297,020
1984-85	$195,000			$492,020

REPORTS

STATUS AND COMMENT

A report on the results of field trials is expected by March 1985.

84/12/01

PROJECT DATA SHEET # 344

TITLE
Optimization of the Shearing Action and Pick Up Efficiency of the RECUFOR Rotor

CONTRACT #
KH405-2-0199 (DSS82-00173)
P-243

CONTRACTOR
Forest Engineering Research
Institute of Canada
143 Place Frontenac
Pointe Claire, Québec
H9R 4Z7

PRINCIPAL INVESTIGATOR
D. Brière

PROGRAM IDENTIFICATION
4.3.5
Biomass Planting, Harvesting and Collection Technologies

DURATION
February 1983 - March 1984

COST
$49,921

SPONSOR
Environment Canada

SCIENTIFIC AUTHORITY
B.J. Sutherland
Great Lakes Forest Research
Centre
Canadian Forestry Service
Department of Environment
P.O. Box 490
Sault Ste. Marie, Ontario
P6A 5M7
Tel.: (705) 949-9461

OBJECTIVE

1. To optimize the RECUFOR rotor/impeller system based on the field test observations.
2. The proposed testing will be aimed at reducing shearing forces and solving problem areas observed during the field tests.
3. To execute the bench tests, analyse the result and produce a final arrangement of the RECUFOR rotor.

DESCRIPTION

Phase I The contractor will establish an experimental design for a series of bench tests to optimize the RECUFOR rotor/impeller system to:
(a) minimize the shearing forces required to process logging residues
(b) reduce the frequency with which residues are entering longitudinally into the rotor
(c) reduce jamming.
Phase II The contractor will conduct bench tests, analyse the test results and make a series of modifications to optimize the performance and efficiency of the rotor/impeller system.
Phase III Following completion of bench testing and data analysis the contractor will provide detail and assembly drawings of the optimized rotor/impeller assembly suitable to enable fabrication by any competent fabrication shop in Canada.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1982-83	$ 25,000			$ 25,000
1983-84	$ 24,421			$ 49,421

REPORTS

STATUS AND COMMENT

This contract has been completed and a final draft report on the improved RECUFOR rotor design has been accepted.

84/12/06

PROJECT DATA SHEET # 359

TITLE Feasibility Study & Design of a Grapple Attachment for Harvesting Hybrid Poplar Stands

CONTRACT #
31155-1-2674-H (OSX81-00125)
31155-1-2674-T (OSX81-00163)
31926-3-0035 (OSX83-00037)

CONTRACTOR
Do-Tan Tool & Gauge
Manufacturing Limited
15 Hatt Street
Dundas, Ontario
L9H 2G1

PRINCIPAL INVESTIGATOR Mr. K.G. Hussey

PROGRAM IDENTIFICATION 4.3.5 Biomass Planting, Harvesting and Collection Technologies

DURATION June 1983 - September 1983

COST $58,937

SPONSOR
Bioenergy Program
National Research Council

SCIENTIFIC AUTHORITY
Theodore B. Golob
National Research Council
Energy Division
Bioenergy Program
Building R-105, Rm 132
Ottawa, Ontario
K1A OR6
Tele.: (613)993-1342

OBJECTIVE

Further testing of the two attachments, the grapple and the front end piler should be planned as a combined testing of the whole harvesting system. It will consist mostly of field testing with a possible further laboratory testing of the grapple oscillator. The front-end piler may require a counter balance weight at the rear. If needed the weight should be designed and installed in the redesign phase of the development.

DESCRIPTION

TASK I A) Addition of counter weights to holder Model 60 Tractor consisting of:-
Bolt on Whell Weights
Hydro-Flation of Tires
Additional Do-Tan Designed weights
B) Increase clearance between lift arm and tractor shroud consisting of:
Wider spacing between lift arms
New brackets for mounting piler to tractor
C) Install body seals in oscillator motor housing
D) Laboratory test the above Modifications

TASK II A) Design and manufacture a new sealed vane oscillator motor with increased torque capacity.
B) Laboratory and field test of new design sealed oscillator motor
Note: It is expected that several designs, redesigns, rework and laboratory tests will be required to achieve acceptable torque.

TASK III Field test front end piler and grapple skidding attachments at Kemptville site.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1981-82	$ 5,567			$ 5,567
1982-83	$ 5,570			$11,137
1983-84	$47,800			$58,937

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 360

TITLE Development of a Felling-Bunching Attachment Phase III

CONTRACT #
31155-1-2674 (0SX81-00129)
31155-2-2633 (0SX82-00061)
31926-3-0038 (0SX83-00039)

CONTRACTOR
Hyd-Mech Forestry Ltd.
239 Beard's Lane
Woodstock, Ontario
N4S 7V9

PRINCIPAL INVESTIGATOR
S. Jasinski
Tele.: (519) 537-6751

PROGRAM IDENTIFICATION
4.3.5
Biomass Planting, Harvesting and Collection Technologies

DURATION July 1982 - March 1984

COST $131,354

SPONSOR
Bioenergy Program
National Research Council

SCIENTIFIC AUTHORITY
T. Golob
National Research Council
Montreal Road
Building R-105, Rm 132
Ottawa, Ontario
K1A 0R6
Tele.: (613) 993-1342

OBJECTIVE

To develop a farm tractor attachment that will harvest 5 year old single stem hybrid poplar plantations. The machine should cut, bunch and unload trees in a continuous, automatic operation at a ground speed of 2.4 km/h and harvest an average of 1,000 trees per working hour.

DESCRIPTION

This development project is a follow-up of a feasibility study completed in the fiscal year 1981-82. The harvesting attachment will be mounted on the loader arms of a Versatile model 160 test tractor. The harvester will be able to operate on the same face of the plantation on either side of the machine; it will prebunch and unload bunches of approximately 15 trees to the free side of the tractor. The trees will be cut with two circular saws; they will be prebunched and unloaded with a system of novel mechanisms powered by a hydraulic pump driven by the tractor power take off. The automatic control system will be provided with a manual override positioned near the operator. The initial field tests are planned for late fall and early winter of 1982, with further tests in plantations during the winter months of 1983. The field tests will continue during the fiscal year 1983/84.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1982-83	$ 98,621			$ 98,621
1983-84	$ 32,733			$131,354

REPORTS

STATUS AND COMMENT

Detailed design drawings have been made and the prototype harvesting attachment has been built and is undergoing preliminary field tests during March 1983. T.B.G. 84/12/07

PROJECT DATA SHEET # 361

TITLE
Reciprocating Tree Cutting Tool - Feasibility Study and Design Concepts Phase III

CONTRACT #
31155-1-2674 (OSX81-00144)
31155-2-2806 (OSX82-00075)
31926-3-0035 (OSX83-00038)

CONTRACTOR
J.D. Reed Machine Limited
53 Empey Street
P.O. Box 188
Brantford, Ontario
N3T 5M8

PRINCIPAL INVESTIGATOR
A. Maiste
Tele.: (519) 753-3909

PROGRAM IDENTIFICATION
4.3.5
Biomass Planting, Harvesting and Collection Technologies

DURATION
January 1982 - March 1984

COST
$106,656

SPONSOR
Bioenergy Program
National Research Council

SCIENTIFIC AUTHORITY
T.B. Golob
National Research Council
Montreal Road
Building R-105, Rm 132
Ottawa, Ontario
K1A 0R6
Tele.: (613) 993-1342

OBJECTIVE

To study the feasibility of felling trees by means of a reciprocating device.
2. To provide design concepts for such a reciprocating tree cutting tool.

DESCRIPTION

Feasibility study and design concepts for a high velocity reciprocating tree cutting tool for five-year old hybrid poplar plantations. The device should be designed to cut one row of trees at a ground speed of approximately 2.5 km/h and should be capable of withstanding the impact on contact with the tree. The study should evaluate knives against a modified saw blade. The width of cut is assumed to be 35 cm.
The cutting device would become a part of a tree harvester attachment for a small agricultural tractor of not more than 70 P.T.O. HP.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1982-83 1983-84	$85,720 $20,936			$ 85,720 $106,656

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 387

TITLE Development of Machinery for Recovery & Preparation of Biomass Feedstocks for Conversion Systems at a Central Tree Processing Complex Phase II

CONTRACT # 23216-3-6245 (OSS83-00063)
C-253

CONTRACTOR Logging Development Corporation
5858 Côte-des-Neiges
Suite 215
Montreal, Québec
H3S 1Z1

PRINCIPAL INVESTIGATOR D.D. Hamilton
Tele.: (514) 739-1791

PROGRAM IDENTIFICATION 4.3.5
Biomass Planting, Harvesting and Collection Technologies

DURATION August 1983 - October 1984

COST $47,024

SPONSOR Energy, Mines & Resources

SCIENTIFIC AUTHORITY A.J. Dolenko
Energy, Mines & Resources
Renewable Energy Division
460 O'Connor Street
Ottawa, Ontario
K1A OE4
tel: (613) 995-9447
Ext. 300

OBJECTIVE

To complete the design and economic analysis carried out under ENFOR Projects P-54 and C-253 relating to the recovery of biomass residues as an operation integrated with those of a central full tree processing complex.

DESCRIPTION

1. To select, size and cost (capital and operating) a system and machinery for handling, converting, and combusting wood residue; sized to match the tree processing complex of ENFOR Project C-253.
2. To verify, by field tests, the efficiency of full tree handling with booms of the Kockum K-100 type.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$47,024			$47,024

REPORTS

HAMILTON D.D., "The Development of Machinery for the Recovery and preparation of Biomass Feedstocks for Conversion Systems at a Central Full Tree Processing complex," ENFOR Project C-253.

STATUS AND COMMENT

PROJECT DATA SHEET # 388		**PROGRAM IDENTIFICATION**	4.3.5 Biomass Planting, Harvesting And Collection Technologies
TITLE	Design & Construction of a Collector for Hybrid Poplar Whips for Cuttings	**DURATION**	September 1983 - February 1985
CONTRACT #	31926-3-5016 (OSX83-00104)	**COST**	$128,966
CONTRACTOR	Hyd-Mech Forestry Ltd. 239 Beard's Lane Woodstock, Ontario N4S 7V9	**SPONSOR**	Bioenergy Program National Research Council
PRINCIPAL INVESTIGATOR	S.K. Jasinski	**SCIENTIFIC AUTHORITY**	T.B. Golob National Research Council Energy Division Building R-105, Rm 132 Ottawa, Ontario K1A OR6 Tele.: (613) 993-1342

OBJECTIVE

The subject of the project is the development of an attachment for a small agricultural tractor that will cut and bundle hybrid poplar whips grown in plantation nurseries. The harvester should cut and bundle one row of poplar whips in a continuous operation.
The project will encompass a feasibility study, design concepts, design, development and testing of an attachment for a small agricultural tractor.
Deliverables will include an analysis of requirements, a feasibility raport, conceptual and simplified design drawings and one experimental prototype. Tractor for prototype will be supplied by NRC.

DESCRIPTION

The initial stages of work will consist of a study to determine feasibility of different design approaches leading to the presentation of design concepts. The study should involve an analysis of operational requirements delineating the proposed design concepts and should be based on given economic and operational constraints. The following general definitions of the feasibility study, design concepts and the prototype development will serve as measurable guidelines for successful completion of the development work.
The project concerns the development of an attachment for a small agricultural tractor that will cut and bundle hybrid poplar whips grown in plantation nurseries. The harvester should cut and bundle one or two rows of poplar whips in a continuous automatic operation.
The feasibility study should include engineering and economic analysis of most likely approaches. The operational ground speed and the density of stems will determine the most desirable size and weight of the attachment.
The following is a proposed breakdown of the development work into individual phases giving the time expected to be required for each phase: a) analysis of requirements, b) feasibility study, c) design concepts, d) detailed design, e) purchased components, fabrication and assembly, f) laboratory tests, continuous - parallel with g), g) redesign and rework, continuous - parallel with f), h) field tests, continuous - paralled with i), i) redesign and rework, continuous - parallel with h).
Each of the above phases is to a large extent, subject to successful completion of the preceding phase as determined by the scientific authority.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$128,966			$128,966

REPORTS

CONTINUED

STATUS AND COMMENT

PROJECT DATA SHEET # 389

TITLE
Development of an Automatic
Poplar Planter

CONTRACT #
31926-3-5014 (OSX83-00105)

CONTRACTOR
Forest Machinery Company
564 Governor's Road
R.R. 3
Dundas, Ontario
L9H 5E3

PROGRAM IDENTIFICATION
4.3.5
Biomass Planting, Harvesting
and Collection Technologies

DURATION
September 1983 - August 1984

COST
$138,054

SPONSOR
Bioenergy Program
National Research Council

SCIENTIFIC AUTHORITY
T.B. Golob
National Research Council
Energy Division
Building R-105, Rm 132
Ottawa, Ontario
K1A 0R6
Tele.: (613) 993-1342

OBJECTIVE

To develop a planter which will automatically pick up individual poplar cuttings from mounted storage magazines, transfer them to a planting device which will insert them into prepared soil and compact the soil around them.

DESCRIPTION

The following tasks will be conducted:

1. Feasibility study, conceptual analysis, and selection of design for planting device and cutting insertion mechanism.
2. Feasibility study, conceptual analysis, and selection of design for a transfer device and magazine to be used in conjunction with the separating mechanism already developed.
3. Feasibility study, conceptual analysis and selection of an overall planter layout using the mechanisms chosen in first two tasks.
4. Complete manufacturing drawings and manufacture the magazine and the transfer mechanism from 2.
5. Laboratory test the magazine and transfer mechanism completed in 4. Revise designs, remanufacture, retest as necessary.
6. Complete manufacturing drawings and manufacture the planting device from 1, and the overall machine from 3.
7. Laboratory test the complete planter completed in 6, revise designs, remanufacture and retest as necessary.
8. Field test the complete planter, revise designs, remanufacture and retest as necessary.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$138,054			$138,054

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET #	390	**PROGRAM IDENTIFICATION**	4.3.5 Biomass Planting, Harvesting and Collection Technologies
TITLE	Mechanization of Energy Plantations - Small Brush Processor	**DURATION**	August 1983 - January 1984
CONTRACT #	31926-3-5015 (OSX83-00082)	**COST**	$46,806
CONTRACTOR	Logging Development Corporation 5858 Côte-des-Neiges Suite 215 Montreal, Québec H3S 1Z1	**SPONSOR**	Bioenergy Program National Research Council
		SCIENTIFIC AUTHORITY	T.B. Golob National Research Council Energy Division Building R-105, Rm 132 Ottawa, Ontario K1A OR6 Tele.: (613) 993-1342

OBJECTIVE

The project will encompass a feasibility study and design concepts leading eventually to the development of a prototype brush processor attachment for a relatively small farm tractor.

DESCRIPTION

The work will comprise a study to determine feasibility of different design approaches leading to the presentation of design concepts. The study should involve an analysis of operational systems supporting the proposed design concepts and should be based on the given economic and operational requirements. The following general definitions of the feasibility study and design concepts will serve as measurable guidelines for a successful completion of the study.

The feasibility study should analyse the two possible approaches, felling chipping and felling bunching of the brush stands. Bunching appeers more desirable than chipping; however, the problems associated with bunching of irregular brush and trees are fairly difficult. The most important components of the attachment are the tree-cutting tool and the accumulating or chipping devices. These devices are in the process of development and the feasibility study for the attachment should be conducted in close cooperation with the developers fo these components.

We prefer to have the attachment designed for our existing test tractor Versatile Model 160; however, the power requirement for the chipping function may indicate that a larger tractor is more suitable then the existing test vehicle. The attachment designed for Versatile 160 could include a small, compact power pack, preferably air cooled. The feasibility study should include engineering and economic analysis of the two possible approaches. The operational ground speed is considered most important. The off-loading and transportation of wood chips are also critical for the acceptability of the overall system.

The following is the proposed breakdown of the study into four phases: a) analysis of requirements, b) feasibility study, c) design concepts, d) cost estimates for the development and commercial production of the attachment. Each phase is, to a large extent, subject to successful completion of the preceding phase as determined by the scientific authority.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$46,806			$46,806

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 400

TITLE	Brainstorming Session Related to Mechanization of Forest Plantations	**PROGRAM IDENTIFICATION**	4.3.5 Biomass Planting, Harvesting and Collection Technologies
		DURATION	November 1983 - May 1984
CONTRACT #	31926-3-5031 (OST83-00231)	**COST**	$40,059
CONTRACTOR	Carleton University Colonel By Drive Ottawa, Ontario K1S 5B6	**SPONSOR**	Bioenergy Program National Research Council
PRINCIPAL INVESTIGATOR	W. Gilles	**SCIENTIFIC AUTHORITY**	T. Golob National Research Council Division of Energy Building R-105, Rm 132 Ottawa, Ontario K1A 0R6 Tele.: (613) 993-1342

OBJECTIVE

This program aims at assisting the Energy Division of the National Research Council's Bioenergy Program in the development of 9 specific pieces of equipment, to be used for planting and harvesting of hybrid poplars or for the preparation of plantations or for processing the harvest.

DESCRIPTION

Each brainstorming project will begin with a briefing of the participants about the design problems to be solved. Data for the briefing will be provide by the NRC.
After the briefing the participants will categorize the problems and establish priorities.
On the basis of these priorities the participants will produce ideas for the solution of the problems.
A typical first session will end with a recapitulation of the problems and possible solutions in the form of prioritized ideas.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$40,059			$40,059

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 404

TITLE Methodology for Establishing Fuel wood Processing Operations

CONTRACT # 31926-3-5036 (OSX83-00185)

CONTRACTOR
Forest Engineering Research
Institute of Canada
143 Place Frontenac
Pointe Claire, Quebec
H9R 4Z7

PRINCIPAL INVESTIGATOR M. Folkema

PROGRAM IDENTIFICATION 4.3.5 Biomass Planting, Harvesting and Collection Technologies

DURATION December 1983 - May 1984

COST $45,121

SPONSOR
Bioenergy Program
National Research Council

SCIENTIFIC AUTHORITY
R. Overend
Division of Energy
National Research Council
Building R-105, Rm 135
Ottawa, Ontario
K1A OR6
Tele.: (613) 993-1342

OBJECTIVE

To produce a well-illustrated, concise and factual handbook on the operation of high-capacity firewood processing centres to permit the production and marketing of firewood at substantially lower costs than conventional firewood operations. These savings can then be passed on to the homeowner by offering lower wood prices.

DESCRIPTION

FERIC has, in-house, the required knowledge and expertise to produce a useful handbook. This knowledge is based on FERIC's 1982 and 1983 studies of several high capacity firewood processors, including the Cord King FM-50, the CTR 1600 and the CMC Technology unit. Also, FERIC has previously produced several handbooks in co-operation with other organizations, e.g. FERIC handbook No. 2 - Handbook for Logging with Farm Tractor - Mounted winches, which was produced jointly with the New Brunswick Forest Extension Service. The proposed handbook will be similar in style and content to Handbook No. 2.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$45,121			$45,121

REPORTS

FOLKEMA M.P., "Handbook on High-Capacity Production and Marketing of Fuelwood," FERIC Handbook No. 6, Sept. 1984.

STATUS AND COMMENT

Completed and report available from the Forest Engineering Research Institute of Canada
R.P.O. 84/11/29

BIOMASS CONVERSION TECHNOLOGIES

Biogas Production

Fermentation to Alcohol

Low Joule Gasification

Medium Joule Gasification

Methanol

Direct Combustion

Char Production

Oil Production - Liquefaction

Chemical Feedstocks

Electrical Generation

Pyrolysis

PROJECT DATA SHEET # 114

TITLE Study of the Upflow, Anaerobic Sludge Blanket Reactor for Methane Production from Food Processing Wastes

CONTRACTOR
National Research Council
Biological Fuels Laboratory
Division of Biological Sciences
Rideau Falls Laboratory
Sussex Drive
Ottawa, Ontario K1A OR6

PRINCIPAL INVESTIGATOR
K.J. Kennedy
S. Guiot
Tel.: (613) 992-3687

PROGRAM IDENTIFICATION
4.3.6.1
Biomass Conversion Technologies/ Biogas Production

DURATION April 1978 - March 1984

COST $360,000

SPONSOR
Division of Biological Sciences
Bioenergy Program
National Research Council
(Liquid Fuels Task)

OBJECTIVE

To evaluate and adapt the anaerobic upflow sludge blanket reactor, originally developed in the Netherlands for mostly soluble wastes, for Canadian wastes and conditions.

DESCRIPTION

Tests with upflow fixed film reactors showed that performance of these reactors is in fact in great measure due to the development of a very active sludge layer in the bottom part of the reactors. Recent tests have shown that methane production rates of over 5 m/m/day can be achieved with wastes suitable for this type of reactor, which was originally developed in the Netherlands and is in commercial use there. Work, has yielded information on engineering aspects of the process, on the type of wastes that can be used and on the advantages and disadvantages of the process in comparison with downflow fixed film reactors. A combination of an upflow sludge blanket and anaerobic filter is proving itself very effective for dilute wastes.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR	BIOLOGICAL SCIENCES	CUMULATIVE TOTAL
1978-79	$ 64,000			$ 64,000
1979-80	$118,000			$182,000
1980-81	$ 80,000			$262,000
1981-82	$ 20,000			$282,000
1982-83	$ 15,000			$297,000
1983-84	$ 40,000		$23,000	$360,000

REPORTS

VAN DEN BERG L., KENNEDY K.J., and Hamoda M.F., "Effect of Type of Waste on Performance of Anaerobic Fixed Film and Upflow Sludge Bed Reactors," Biological Sciences, National Research Council of Canada, Ottawa, Ontario. K1A OR6. 1981 NRCC #19315. (Available from authors)
VAN DEN BERG L., and KENNEDY K.J., "Potential Use of Anaerobic Processes for Industrial Waste Treatment", 1981 NRCC #19727. (Available from authors)
GUIOT S.R., and VAN DEN BERG L., "Performance and Biomass Retention of and Upflow Anaerobic Reactor Combining an Sludge Blanket and a Filter," Biotechnology Letter, 6, 161-164 (1984).
GUIOT S.R., and VAN DEN BERG L., "Dynamic Performance of an Anaerobic Reactor Combining an Upflow Sludge Blanket and a filter for the Treatment of Sugar Waste," 39th Purdue Industrial Waste Conference, 1984. NRCC # 23409. (Available from authors).

CONTINUED

STATUS AND COMMENT

There is considerable commercial interest in the new combination reactor.
84/12/04

1978-83: Funding from both sources under "Sponsor"

PROJECT DATA SHEET # 115

TITLE Evaluation of downflow anaerobic fixed film reactors for methane production from wastes

CONTRACTOR National Research Council
Biological Fuels Laboratory
Division of Biological Sciences
Rideau Falls Building
Ottawa, Ont. K1A 0R6

PRINCIPAL INVESTIGATOR K.J. Kennedy,
R.J. Samson,
L. van•den•Berg
Tel.: (613) 992-3687

PROGRAM IDENTIFICATION 4.3.6.1
Biomass Conversion Technologies/
Biogas Production

DURATION April 1978 - March 1984

COST $773,000

SPONSOR Division of Biological Sciences
Bioenergy Program
National Research Council
(Liquid Fuels Task)

OBJECTIVE

To optimize reactor performance, to study methane production and pollution removal with citric acid waste, fish processing waste, dairy waste, masonite processing waste, pulping waste and stillage waste and to evaluate commercial film supports.

DESCRIPTION

Studies showed that methanogens attach themselves readily to solid supports and are not readily washed out. Once a film was formed on the support, it was not easily removed and was very active. These characteristics turned out to be very important for the performance of the downflow stationary fixed film (DSFF) reactor.
Many of the practical aspects of this reactor have now been studied in considerable detail. These include start-up phenomena, effects of support material on start-up and performance, effects of type and concentration of waste and its nutrient content, and effects of temperature, reactor size and effluent recirculation. In addition, non-steady state effects, such as caused by rapid change over from one waste to another, by hydraulic and organic overloading, by intermittent loading and by long periods of starvation were studied.

FUNDING

FISCAL YEAR	SPONSOR	BIOLOGICAL SCIENCES		CUMULATIVE TOTAL
1978-79	$ 63,000			$ 63,000
1979-80	$118,000			$181,000
1980-81	$130,000			$311,000
1981-82	$170,000			$481,000
1982-83	$200,000			$681,000
1983-84	$ 30,000	$22,000		$773,000

REPORTS

COPP G.H., and KENNEDY K.J., "Support Materials for Downflow Stationary Fixed Film (DSFF) Methanogenic Reactors," J. Ferm. Tech., 61,333-336, 1984.
KENNEDY K.J. and MUZAN M., "Continuous pH Measurement for Anaerobic Digestion," Biotech. and Bioeng., 26,627, 1984.
VAN DEN BERG L. and KENNEDY K.J. "Dairy Waste Treatment with Anaerobic Stationary Fixed Film Reactors," Wat. Sci. Tech., 15, 359-368, 1983.
VAN DEN BERG L., and KENNEDY K.J. "Comparison of Advanced Anaerobic Reactors," Proc. 3rd Int. Conf. on Anaerobic digestion, Boston, 71-89, 1983.

CONTINUED

STATUS AND COMMENT

Results were confirmed in larger scale test in an industrial laboratory and at the Wastewater Technology Center in Burlington. Commercial scale systems are operating or under construction.

84/12/03

1978-83: Funding from both sources under "Sponsor"

PROJECT DATA SHEET # 368

TITLE Studies on Energy Production by High Rate Anaerobic Fermentation

CONTRACT # In-House

CONTRACTOR Waste Water Technology Center
Cooperative project of Environment Canada and the National Research Council

PRINCIPAL INVESTIGATOR L. van den Berg
B.E. Jank
E. Hall

PROGRAM IDENTIFICATION 4.3.6.1
Biomass Conversion Technology/ Biogas Production

DURATION April 1979 - March 1984

COST $476,500

SPONSOR Division of Biological Sciences
Energy Program
National Research Council

SCIENTIFIC AUTHORITY L. van den Berg
Biological Sciences
National Research Council
Ottawa, Ontario
K1A 0R6
Tele.: (613) 992-3310

OBJECTIVE

The development, testing and demonstration of an automated process monitoring and control package for high rate anaerobic reactors.
The identification of design and operational constraints on high rate anaerobic reactors for: energy production, pollution control, unsteady state operation.

DESCRIPTION

1) Suitable monitoring Instrumentation will be identified and tested.
2) The selection process monitoring equipment will be utilized on the anaerobic pilot plant to perform dynamic experiments to dientify the magnitude and direction of various system responses to perturbations. Data acquisition software will be developed.
3) The transient information will be interpreted and utilized in the construction of a process control algorithm. The system will be tested and verified by subjecting the pilot plant to transient loads and if feasible, allowing the automation package to take a reactor through process start-up.
4) Finally the control system will be translated to a self contained, low-cost microprocessor-based package suitable for field installation.
5) Where possible, the equipment used will be suitable for commercial application on full-scale reactors. At the end of the experimental program the following will be made available to NRC and potential users: a) specifications for monitoring and controlling equipment, b) full system drawings, c) operating instructions, d) monitoring and control software, e) testing and demonstration results.

If a suitable full-scale reactor is available at the conclusion of this study, the WTC would consider designing an experimental program and providing the technology for further demonstration.

FUNDING

FISCAL YEAR	SPONSOR	ENVIRON.		CUMULATIVE TOTAL
1979-80	$20,000	$60,800		$ 80,000
1980-81	$77,200	$34,000		$191,200
1981-82	$68,000	$27,500		$286,700
1982-83	$76,600	$53,200		$416,500
1983-84	$60,000			$476,500

REPORTS

CONTINUED

STATUS AND COMMENT

The objectives of Phase I have been achieved and a final report will be filed. It was concluded that before an operational pilot plant can be promoted some work needs to be done on process controls. This was started in 1983 and is continuing under a different program.

84/12/06

PROJECT DATA SHEET #	20
TITLE	Development, operation and demonstration of a farm scale anaerobic digester for production of methane from hog manure.
CONTRACT #	07SZ.01843-7-0752 (OSZ77-0152)
CONTRACTOR	John Fallis, RR 3, Millbrook, Ontario. LOA 1GO
PRINCIPAL INVESTIGATOR	John Fallis Tel.: (705) 932-5568
PROGRAM IDENTIFICATION	4.3.6.1 Biomass Conversion Technologies/ Biogas Production
DURATION	October 1977 - December 1984
COST	$86,360
SPONSOR	Agriculture Canada
SCIENTIFIC AUTHORITY	R. Hocking Engineering & Statistical Research Institute Research Branch Agriculture Canada Bldg. 94 Ottawa, Ontario Tel.: (613) 995-9671

OBJECTIVE

To develop and operate a farm scale anaerobic digester for production of methane from hog manure.

DESCRIPTION

1. An anaerobic digester for the production of methane gas from hog manure based on the design produced by D. Young of Midwest Silos has been constructed.
2. The operation of the system using the manure from the 700-1500 hogs is being tested and monitored.
3. Collection and summary of data on temperature, gas production, energy inputs, loading rates, digestor effects, net yields of energy, and management of operational requirements will be detailed in the final report.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1977-78	$16,384			$16,384
1978-79	$ 8,976			$25,360
1979-80	$ 4,000			$29,360
1980-81	$ 4,000			$33,360
1981-82	$15,000			$42,360
1982-83	$29,000			$71,360
1983-84	$15,000			$86,360

REPORTS

STATUS AND COMMENT

The system was in limited operation over the summer of 1983. Glycol leaks from the heating system necessitated a shut down in the fall. A high solids content as well as time and weather limitations prevented entry into the digester for repairs. The system was closed for the winter. With the evolution of new improved designs and data available from these digesters the decision to terminate this contract was taken in the spring of 1984. A final report will be due from the contractor in December 1984.

84/12/04

PROJECT DATA SHEET #	237	**PROGRAM IDENTIFICATION**	4.3.6.1 Biomass Conversion Technologies/ Biogas Production
TITLE	Upgrading Waste Biomass into Methane Fuel Gas by Anaerobic Fermentation	**DURATION**	November 1981 - November 1984
CONTRACT #	Strategic Grant	**COST**	$60,600
CONTRACTOR	University of Waterloo Department of Chemical Engineering Waterloo, Ontario N2L 3G1	**SPONSOR**	Natural Sciences and Engineering Research Council
PRINCIPAL INVESTIGATOR	M. Moo-Young		

OBJECTIVE

In the proposed research, we plan to apply our previously-attained expertise in anaerobic digestion in order to develop a free-standing anaerobic fermentation process which will generate fuel gas as the main product. We intend to determine the solids conversion efficiency (liters gas produced/g solids added) and the concomitant gas generation rate for a range of agricultural and forestry wastes (separately and in combinations) which are widely available in Canada. The experimental work will be performed in existing demonstration units now being operated in our engineering analysis of the process energy budget for the various cases and to perform a detailed economic analysis of a number of scenarios pertinent to the types of raw materials available in representative regions of Canada.

DESCRIPTION

The work program is divided into four areas:

1) A state-of-the-art review of the relevant literature.
2) Design and construction of experimental equipment.
3) Experimental studies of co-digestion of manures and cellulosic residues, slected as grass, straw and corn stover.
4) Development and application of a computer program for processing economic evaluations.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1981-82 1982-83 1983-84	$22,200 $22,200 $16,200			$22,200 $44,400 $60,600

REPORTS

CHAHAL D.S., VLACH D., MOO-YOUNG M., "Effect of physical and physicochemical pretreatments of wood for SCP production with C. cellulolyticum," Biotechnol. Bioeng. In press (Accepted March 1981)

MOO-YOUNG M., CHAHAL D.S., STICKNEY B.,"Pollution control of swine manure and straw by conversion to C. cellulotyticum SCP feed," Biotechnol. Bioeng. In press (Accepted March 1981).

MOO-YOUNG M., MACDONALD D.G., "Improved economics of the Waterloo SCP process by increasing growth rates," Biotechnol. Letters, 3, 149-152 (1981).

GONZALEZ-VALDES A., MOO-YOUNG M., "Production of yeast SCP from corn stover hydrolysates," Biotechnol. Letters, 3, 143-148 (1981).

CONTINUED

STATUS AND COMMENT

Working in collaboration with J.M. Scharer and C.W. Robinson. See project #38 for previous work under Strategic Grant 1978-1981.
The evaluations for agricultural wastes and crop residues are nearing completion and process design criteria are being established. The experimental research on forestry wastes have not yet started. Equipment is now in place to test the potential utilization of forestry residues for biogas production with concurrent pollution abatement of the wastes. 84/12/07

PROJECT DATA SHEET # 285

TITLE Demonstration of Fixed Film Anaerobic Reactor

CONTRACT # DRECT

CONTRACTOR
Agropur
C.P. 6000
510 Principale
Granby, Quebec
J2G 7G2

PRINCIPAL INVESTIGATOR Roeland H. Peters

PROGRAM IDENTIFICATION 4.3.6.1
Biomass Conversion Technologies/ Biogas Production

DURATION April 1981 - March 1984

COST $1,658,000

SPONSOR Environment Canada

SCIENTIFIC AUTHORITY
R.L. Christensen
Waste Management Branch
Environmental Proctection Service
Place Vincent Massey
351 St. Joseph Blvd.
Hull, Quebec K1A 1C8
Tele: (613) 997-4334

OBJECTIVE

1. Reducing BOD load of wastewater by 70% anaerobicaly and 98% over all.
2. Producing 1385 m/d methane gas to replace 1194 L. of imported #6 bunker C fuel oil.
3. Eliminating 7200 kWh/d of electrical energy consumption otherwise required to reduce BOD load aerobicaly.
4. Proving 97% BOD reduction with aerated lagoon under Canadian winter conditions.

DESCRIPTION

1. Engineering & Design

The contractor will design and build a unique wastewater treatment plant for dairy waste that will eliminate 7200 kWh/d of electrical energy consumption otherwise required for a standard aerobic system and also produce methane gas that will be burned to produce steam at a rate of 700 kg/h. The system will consist of two anaerobic fixed film reactors and other peripherals such as a solid screen, lagoons etc.

2. Construction & Installation

The contractor will construct the wastewater treatment plant on a piece of land to be purchased next to their cheese and whey powder process plant in Notre-Dame-du-Bon-Conseil. The land necessary to build the wastewater plant including the buffer zone to nearest residence is 16 ha. The construction will include: a pumping station with submersible pumps; primary treatment including a degritting channel, the equalization basin with mechanical mixers, and two anaerobic fixed film fermenters, two aerated lagoons, two polishing lagoons and an out fall to the Nicolet River.

3. Testing & Monitoring Program

Following successful completion of the start-up program, the plant shall undergo a 40 weeks performance monitoring program.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1981-82	$ 88,000			$ 88,000
1982-83	$200,000			$ 288,000
1983-84	$ 37,500			$ 325,500
1981-83		$1,332,500		$1,658,000

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 286

TITLE
Mobile Anaerobic Fixed-Film Reactor

CONTRACT #
1. 31028-1-2442 (DSC81-299)
2. 31028-2-2069
3. 31028-2-2788
4. 31028-2-2057
5. 31028-2-2561

CONTRACTOR
1. J.D. Koppernaes Eng. Ltd.
Bedford, Nova Scotia
2. J.D. Koppernaes Eng. Ltd.
Bedford, Nova Scotia
3. IMP
Halifax, Nova Scotia
4. Wilson Trucks
Truro, Nova Scotia
5. J.D. Koppernaes Eng. Ltd.
Bedford, Nova Scotia
6. ADI Ltd.
Frederiction, N.B.
7. Porter Dillon
Halifax, N.S.

PROGRAM IDENTIFICATION
4.3.6.1
Biomass Conversion Technolcgies/
Biogas Production

DURATION December 1981 - March 1985

COST $149,987

SPONSOR
Bioenergy Program
National Research Council
(Liquid Fuels Taks)

SCIENTIFIC AUTHORITY
D. Robson (Projects #1 - 4)
Atlantic Regional Laboratory
1411 Oxford Street
Halifax, Nova Scotia
B3H 3Z1
Tele: (902) 426-8271
K.J. Kennedy
Biological Sciences
National Research Council
Ottawa, Ontario
K1A OR6
Tele.: (613) 992-3310

OBJECTIVE

1. Construct a mobile down-flow fixed film reactor and install in a mobile trailer.
2. Conduct research trials on waste from food processing plants and other organic sources in the Maritime provinces.

DESCRIPTION

A number of small contracts have been let for the initial construction of the mobile reactor and the subsequent management and operation of the system at a variety of locations in the Maritimes. The project is being managed by the NRC laboratory in Halifax.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1981-82	$ 7,827 design			$ 7,827
1982-83	$ 7,415 const.			$ 15,242
1982-83	$ 9,900 reactor			$ 25,142
1982-83	$40,445 trailer			$ 65,587
1982-83	$14,400 trials			$ 79,987
1983-84	$40,000			$119,987
1984-85	$30,000			$149,987

REPORTS

Operation of Downflow Stationary Fixed Film Reactor at Fish Reductions Limited,
J.D. Koppernaes Engineering, 1984

CONTINUED

STATUS AND COMMENT

The mobile research facility was and will be used at several food processing plants to gain information on reactor performance under practical conditions.

A recent test was conducted on leachate form a landfill site. The results from the leachate treatment were highly satisfactory suggesting the suitability of the fixed film reactor for this purpose

84/12/01

PROJECT DATA SHEET #	288	**PROGRAM IDENTIFICATION**	4.3.6.1 Biomass Conversion Technologies/ Biogas Production
TITLE	Improving Production and Reliability of Methane Digesters	**DURATION**	January 1982 - March 1985
CONTRACT #	01843-1-ER16 (OSU82-00016)	**COST**	$332,760
CONTRACTOR	University of British Columbia Dept of Bio-Resource Engineering 2075 Wesbrook Mall Vancouver, B.C. V6T 1W5	**SPONSOR**	Agriculture Canada
PRINCIPAL INVESTIGATOR	K.V. Lo	**SCIENTIFIC AUTHORITY**	D. Marshall Engineering & Statistical Research Institute Research Branch Agriculture Canada Ottawa, Ontario K1A 0C6 Tel.: (613) 995-9671

OBJECTIVE

1. Investigate feasibility of increasing biogas production using advanced reactor concepts with liquid-solids separation pretreatment.
2. Develop design criteria for construction of on-farm scrubbers for removal of carbon dioxide and hydrogen sulfide from biogas.
3. To investigate the development of a pH and a methane sensor suitable for continuous monitoring of on-farm methane digesters.

DESCRIPTION

Project 1

Phase I To select the proper screen size for liquid-solid separation pretreatment based on optimum volatile solid levels and compare the rate of biogas production from various laboratory-scale and conventional reactors.

Phase II To evaluate the most promising reactors on a pilot scale and to produce design criteria for assessment of farm scale advanced concept reactors.

Project 2

Phase I To compare the effectiveness of various scrubbing systems and to develop design criteria for the development of an on-farm biogas scrubber.

Phase II To field test the scrubbers with pilot-scale digesters and to make the necessary modifications.

Project 3

Phase I To select, study and recommend a pH sensor suitable for continuous use in on-farm digesters and for digester control systems and develop a methane concentration sensor suitable for farm use.

Phase II To field test the pH and methane sensors with pilot-scale digesters.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1981-82	$ 86,468			$ 86,468
1982-83	$155,292			$241,760
1983-84	$ 70,000			$311,760
1984-85	$ 21,000			$332,760

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 289		**PROGRAM IDENTIFICATION**	4.3.6.1 Biomass Conversion Technologies/ Biogas Production
TITLE	Design, Fabrication and Monitoring of a Complete Anaerobic Hog Waste Treatment System with Energy Recovery	**DURATION**	March 1982 - March 1985
		COST	$415,283
CONTRACT #	01916-1-ER17 (OSZ82-00049)	**SPONSOR**	Agriculture Canada
CONTRACTOR	McLaren Engineers, Planners and Scientists Inc. 320 Adelaide Street South London, Ontario N5Z 3L2	**SCIENTIFIC AUTHORITY**	D. Marshall Engineering & Statistical Research Institute Research Branch Agriculture Canada Ottawa, Ontario K1A 0C6 Tel.: (613) 995-9671

OBJECTIVE

1. develop a design for hog waste treatment including gas storage and cleaning with an energy recovery system using the latest technology
2. construct and monitor a demonstration plant and to develop, in cooperation with a manufacturer of farm equipment, a packaged design to be marketed and made available to the hog industry. It will be a mesophillic process for a 700-hog operation.

DESCRIPTION

1. The contractor shall evaluate currently available anaerobic digester designs with specific reference to the following factors:
   a) Environmental Factors 1) pH; 2) alkalinity; 3) volatile acid concentrations; 4) temperature; 5) nutrient availability; 6) toxic materials.
   b) Operational Factors 1) composition of organic substrate; 2) retention time; 3) concentration of substrate; 4) organic loading rate; 5) degree of mixing; 6) heating and heat balance; 7) concentration of effluent; 8) nutrients in effluent; 9) sensitivity to hydraulic, temperature and loading irregularities.
2. The contractor shall complete a detailed design including a detailed cost estimate and economic evaluation including the potential for recovery of protein from the waste.
3. The contractor shall ensure the construction of an anaerobic waste treatment facility as developed in stage 1 and 2 adjacent to existing hog barns.
4. The contractor shall operate and monitor the facility and prepare a final report detailing the design, construction and performance of the system.
5. The contractor is to prepare a report outlining design requirements for a packaged system, using data and design parameters obtained in the demonstration plant work in phase 4.

A packaged system based on the demonstration plant design would be prepared complete with an economic evaluation, energy balance and overall treatment efficiency assessment. The package system could then be marketed through the joint venture company which would combine the engineering equipment supply and marketing expertise from the proponents.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1981-82	$ 86,468			$ 86,468
1982-83	$149,283			$235,751
1983-84	$ 42,000			$277,283
1984-85	$ 38,000			$415,283

REPORTS

CONTINUED

STATUS AND COMMENT

PROJECT DATA SHEET #	319	**PROGRAM IDENTIFICATION**	4.3.6.1 Biomass Conversion Technologies/ Biogas Production
TITLE	Biological Process Application for Biogas Production and Waste Treatment	**DURATION**	November 1982 - November 1985
CONTRACT #	Strategic Grant	**COST**	$127,404
CONTRACTOR	University of British Columbia Bio-Resource Eng. Dept. Vancouver, B.C. V6T 1W5	**SPONSOR**	Natural Sciences and Engineering Research Council
PRINCIPAL INVESTIGATOR	Kwang Victor Lo		

OBJECTIVE

The overall objective of the proposed research is to develop an efficient integrated biogas production and waste treatment system for wet biomass such as animal manures and food processing wastes.

DESCRIPTION

1. To develop an efficient liquid-solid separator that is capable of providing a liquid manure filtrate with optimal volatile solids content for efficient biogas production;
2. To investigate the feasibility of significantly increasing biogas production per unit volume of digester through the use of the advanced reactor concepts (fixed film reactor (NRC)), fluidized bed reactor (Dorr-Oliver), etc.)preceded by liquid-solid separation of the feed stock;
3. To study the feasibility of combining a thermophilic aerobic digester and a mesophilic anaerobic digester for more efficient biogas production and animal waste treatment;
4. To process the thermohpilically digested solids for animal feed recovery;
5. To develop a microprocessor assisted control and monitoring system for animal manure treatment and biogas production.

Incorporating the components above, we are confident that a highly efficient and reliable biogas production and waste treatment system with feed recovery could be developed.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1982-83	$39,000			$ 39,000
1983-84	$44,520			$ 83,520
1984-85	$43,884			$127,404

REPORTS

LO K.V. et al, "The Effect of Solid-Separation Pretreatment on Biogas Production from Dairy Manure," Agricultural Wastes, 8 (1983) 155-165.

LO K.V. et al, "Methane Production from Screened Dairy Manure Using A Fixed-Film Reactor," 1984 Agricultural Wastes, 9 (1984) 175-188.

LIAO P.H. et al, "Effect of Liquid-Solids Separation on Biogas Production from Dairy Manure," Energy in Agriculture, 3 (1984) 61-69.

STATUS AND COMMENT

Working in collaboration with N. Ross Bulley, Bio-Resource Engineering Dept. K.V.L.
84/12/04

PROJECT DATA SHEET # 342		**PROGRAM IDENTIFICATION**	4.3.6.1 Biomass Conversion Technologies/ Biogas Production
TITLE	Development of Computer Control System for Anaerobic Reactors	**DURATION**	April 1982 - March 1984
CONTRACTOR	National Research Council Division of Biological Sciences 100 Sussex Drive Ottawa, Ontario K1A OR6	**COST**	$70,000
		SPONSOR	Division of Biological Sciences Bioenergy Program National Research Council
PRINCIPAL INVESTIGATOR	M.F. Podruzny		

OBJECTIVE

To develop a micro-computer package suitable for industrial use and capable of controlling reactors under most operating conditions and of alerting operators of problems outside its control.

DESCRIPTION

Advanced anaerobic digestion processes with rapid production of methane are becoming recognized as an economical method of waste stabilization for industrial and farming applications. However, the methods of control of these fast processes demand, at present, the availability of expensive analytical equipment and highly trained technical staff. Neither equipment nor staff may be available under many conditions, and this would severely limit application of advanced and novel technologies.

To alleviate the need for analytical equipment and trained staff a computer control system is being developed. Since gas production is a very sensitive indicator of digester performance and can be measured readily, it was chosen as the controlled variable and feed rate as the manipulated variable. The main aim of the project is to develop a package that would under most operating conditions maintain the performance of the process and in the event of a severe upset would signal that a problem existed to allow remedial action to be taken.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1982-83	$ 50,000			$ 50,000
1983-84	$ 20,000			$ 70,000

REPORTS

PODRUZNY M.F. and VAN DEN BERG L., "Development of a computer control system for anaerobic methane producing reactors," Biotechn. Bioeng., 26 p 392-393, 1984.

STATUS AND COMMENT

The computer program developed and tested in the laboratory was further modified and incorporated in a controller by the Manitoba Research Council under an Energy Contract. This controller remained very sluggish, however, and over-reacted to the reduction in gas production. Improvement of these factors may require a revision of software, probably requiring a more intensive study of the process and use of extra sensors. The project has been terminated for the time being.

84/12/06

PROJECT DATA SHEET # 343

TITLE Anaerobic Fixed Film Development and Performance

CONTRACTOR
National Research Council
Division of Biological Sciences
100 Sussex Drive
Ottawa, Ontario
K1A 0R6

PRINCIPAL INVESTIGATOR
K.J. Kennedy
R. Samson

PROGRAM IDENTIFICATION
4.3.6.1
Biomass Conversion Technologies/ Biogas Production

DURATION April 1982 - March 1985

COST $177,000

SPONSOR
Division of Biological Sciences
Bioenergy Program
National Research Council

OBJECTIVE

To optimize microbial film performance through a better understanding of film development and to determine effects of waste composition, recirculation and temperature on film formation and kinetics.

DESCRIPTION

Several basic questions were raised during the last few years of research on the development of the fixed film reactor into a commercially attractive system. These questions can only be answered by in-depth studies of the reactor. These studies are now underway and involve a detailed look at film development, a study of ecological developments in the film, and precise measurements of mixing in single and multichannel reactors, in relation to rector performance. Mathematical models to describe and predict reactor performance are being developed and localization of acid and methane production has been demonstrated. The work will continue to increase our understanding of fixed film reactors and to assist in developing improved reactors and assessing performance of other reactors such as the upflow sludge blanket reactor. The latter reactor was studied in some detail by a post graduate student (Project #114) and is also being installed now commercially in Canada.

FUNDING

FISCAL YEAR	SPONSOR	BIOLOGICAL		CUMULATIVE TOTAL
1982-83	$ 60,000			$ 60,000
1983-84	$ 65,000			$125,000
1984-85	$ 32,000	$20,000		$177,000

REPORTS

KENNEDY K.J. and VAN DEN BERG L., "Effect of Height on the Performance of Anaerobic Downflow Stationary Fixed-Film Reactors Treating Bean Blanching Waste," Proc. of the 37th Industrial Waste Conference, Purdue University, May 10-12, 1982.

KENNEDY K.J. and DROSTE R.L., "Effect of Influent Concentration on the Startup of Downflow Stationary Fixed-Film Reactors," Proc. of the 38th Industrial Waste Conference, Purdue University, 615-627, May 10-12, 1983.

TRUDELL M., "Treatment of High Strength, Acidic, Organic Wastewaters," M. A. Sc. Thesis, University of Western Ontario, London Ontario, 1983.

STATUS AND COMMENT

PROJECT DATA SHEET # 379

TITLE Evaluation & Optimization of Protein Recovery from Anaerobically Fermented Beef Cattle Feed Lot Wastes

CONTRACT # 01916-1-ER14 (DSZ81-00128)

CONTRACTOR
Canviro Consultants Ltd.
178 Louise Street
Kitchener, Ontario
N2H 5M5

PRINCIPAL INVESTIGATOR R.J. Rush

PROGRAM IDENTIFICATION 4.3.6.1 Biomass Conversion Technologies/ Biogas Production

DURATION January 1982 - April 1984

COST $141,000

SPONSOR Agriculture Canada

SCIENTIFIC AUTHORITY
D. Marshall
Engineering and Statistical Research Institute
Agriculture Canada
Ottawa, Ontario
K1A 0C6
Tele.: (613) 995-9671

OBJECTIVE

DESCRIPTION

Phase I

Within five (5) months from the date of the contract the contractor shall review laboratory methods currently used to determine crude protein content of manure, fermentation effluents and protein cakes, with the purpose of developing a standard procedure for the analysis of these samples; and to evaluate and quantify the analytical errors involved in the determination. The standard procedure should have a correlation with large scale recoverability.

Phase II

Within nine (9) months from the start of this stage the contractor shall perform fractionation of the total solids in the raw manure and fermenter effluent to establish a relationship between the various solid fractions and their crude protein contents, and to study the physical characterisitic (particle size, particle density, etc.) to provide some insight into the applicability of centrifugation for protein recovery. This information will also be valuable in assessing other protein recovery methods.

Phase III

Within eight (8) months from the start of this stage the contractor shall review and modify existing bench-scale centrifuge techniques, and evaluate this developed technique by performing a number of parallel full-scale centrifuge runs to provide a scale-up relationship, using the information obtained in Phase II.

Phase IV

Within ten (10) months from commencement of this stage of the contract the contractor shall study the effect of fermentation operational parameters on protein recovery and feed value using laboratory-scale fermentation units; and if possible, develop an operational strategy involving operational parameter, protein recovery and protein value (digestibility).

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1981-82	$18,000			$ 18,000
1982-83	$55,000			$ 73,000
1983-84	$60,000			$133,000
1984-85	$ 8,000			$141,000

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET #	402	**PROGRAM IDENTIFICATION**	4.3.6.1 Biomass Conversion Technologies/ Biogas Production
TITLE	Evaluation - Product for Stimulating anaerobic Digestion	**DURATION**	February 1984 - March 1985
CONTRACT #	31926-3-5032 (0ST83-00331)	**COST**	$11,184
CONTRACTOR	University of British Columbia Attn: Dr. R.D. Spratley 2975 Wesbrook Mall Vancouver, British Columbia V6T 1W5	**SPONSOR**	Bioenergy Program National Research Council
PRINCIPAL INVESTIGATOR	V. Lo	**SCIENTIFIC AUTHORITY**	L. van den Berg National Research Council Biological Sciences Ottawa, Ontario K1A 0R6 Tele.: (613) 992-3310

OBJECTIVE

To evaluate the usefulness of a commercial product claimed to be beneficial in the start-up and operation of anaerobic digesters and to test for:

A. the presence of methanogenic activity.
B. the presence of factors stimulating methanogenic activity.
C. the activity of the material in laboratory fixed film reactors under operating conditions.

DESCRIPTION

Tests were made with methanogenic cultures and with down flow stationary fixed film reactors. Each test was down in triplicate and then repeated.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1983-84	$ 7,700			$ 7,700
1984-85	$ 3,484			$11,184

REPORTS

LO K.V. and CHEN W.Y., "Tests on the Properties of the Commercial Product (BR-90), provided by Canber Industries Limited," Final Report.

STATUS AND COMMENT

Results from this completed study have shown that the product did not have methanogenic activity and did not stimulate methane production of a suspended methanogenic culture. Methane production of a fixed film reactor was stimulated during addition of the product because it provided a readily degradable carbon source.

84/12/06

PROJECT DATA SHEET # 472		**PROGRAM IDENTIFICATION**	4.3.6.1 Biomass Conversion Technologies/ Biogas Production
TITLE	Pig Manure Digester: Construction and Experimentation	**DURATION**	October 1983 - December 1985
CONTRACT #	01916-3-ER34	**COST**	$393,000
CONTRACTOR	Centre de Recherche Industrielle du Québec Sainte-Foy, Québec	**SPONSOR**	Agriculture Canada
PRINCIPAL INVESTIGATOR	D. Morrissette	**SCIENTIFIC AUTHORITY**	R. Chagnon Station de recherches de St-Jean Agriculture Canada Case postale 457 430 boul Gouin St-Jean, Québec J3B 6Z8

OBJECTIVE

To construct and test a 50 m, cement fixed-film anaerobic digester which was designed under contract 01843-1-ER15. The biogas produced from pig manure will be used for the production of electricity and heat.

DESCRIPTION

Phase I : Complete the design of the system, construct the digester, and purchase and install the equipment and instrumentation.
Phase II : Test the system under various conditions. Evaluate the performance and the limits of the digester. Carry out an energy balance. Verify the production of electricity using an induction motor.
PhaseIII : Carry out an overall assessment of the work including: the modifications required to the original design; installation and operational problems. Revise plans for the digester.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1983-84	$105,000			$105,000
1984-85	$150,000			$255,000
1985-86	$138,000			$393,000

REPORTS

No reports are available at this time

STATUS AND COMMENT

The digester is built and experimental studies have started.

84/12/06

PROJECT DATA SHEET #	473	**PROGRAM IDENTIFICATION**	4.3.6.1 Biomass Conversion Technologies/ Biogas Production
TITLE	Solids Rentention Time Control for Advanced Reactor Concepts	**DURATION**	April 1983 - March 1985
CONTRACT #	E2041 ER42	**COST**	$80,000
CONTRACTOR	Roslyn Park Farm Ltd. Petersburg, Ontario	**SPONSOR**	Agriculture Canada
PRINCIPAL INVESTIGATOR	R.C. Bechtel	**SCIENTIFIC AUTHORITY**	D. Marshall Engineering & Statistical Research Institute Energy Section Agriculture Canada Ottawa, Ontario K1A OC6 Tele.: (613) 995-9671

OBJECTIVE

To study the increase of productivity of a full-scale completely mixed digester by returning a part of the effluent micro-organism content to the digester thus increasing the solid retention time (SRT) and/or enable a reduction in the hydraulic retention time (HRT) without the possibility of "wash-out". Final goal being to produce more biogas per volume unit of digester by digesting more manure per volume unit of digester and also to study if operating temperature could be reduced using this operating method.

DESCRIPTION

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1983-84 1984-85	$30,000 $50,000			$30,000 $80,000

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET #	474	**PROGRAM IDENTIFICATION**	4.3.6.1 Biomass Conversion Technologies/ Biogas Production
TITLE	Mobile Anaerobic Digestion Facility	**DURATION**	April 1983 - March 1985
CONTRACT #	E2042 ER47	**COST**	$310,000
CONTRACTOR	Canviro Consultants Ltd. Kitchener, Ontario	**SPONSOR**	Agriculture Canada
PRINCIPAL INVESTIGATOR	R.J. Rush	**SCIENTIFIC AUTHORITY**	D. Marshall Engineering & Statistical Research Institute Research Section Agriculture Canada Ottawa, Ontario K2A OC6 Tele.: (613) 995-9671

OBJECTIVE

Phase I: Complete turn key design and construction of a mobile anaerobic digestion facility with 2 digester (completely mixed and fixed film), mobile trailer with fifth wheel attachment, gas handling and storing systems, feed and effluent handling systems, hot water biogas or propane fueled boiler, work bench and laboratory sink for a total of 89 K.
OPTION A: Biogas fueled electrical generation system (15 KVA) installed for 20 K.
OPTION B: Protein recovery system with centrifuge system installed for 83 K.
OPTION C: Biogas scrubbing, drying and high pressure storage system installed for 16 K.
OPTION D: pH control and nutrient addition system installed for 9 K.
Phase II: Facility performance evaluation.
A: Start-up and 4 months performance evaluation at Selves Farms for 46 K.
B: 4 months performance evaluation at Kemptville College for 49 K.
C: 4 months performance evaluation at Meat Packing Plant for 46 K.
Phase III: Future demonstration elsewhere for 10 to 15 K/month.

DESCRIPTION

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1983-84	$240,000			$240,000
1984-85	$ 70,000			$310,000

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET #	475	**PROGRAM IDENTIFICATION**	4.3.6.1 Biomass Conversion Technologies/ Biogas Production
TITLE	Purification of Biogas		
CONTRACT #	01916-3-ER33	**DURATION**	October 1984 - October 1985
CONTRACTOR	Centre de recherche industrielle du Québec Sainte-Foy, Québec	**COST**	$44,526
		SPONSOR	Agriculture Canada
PRINCIPAL INVESTIGATOR	P. Toupin	**SCIENTIFIC AUTHORITY**	R. Chagnon Station de recherches de St-Jean Agriculture Canada Case postale 457 430 boul. Gouin St-Jean, Québec J3B 6Z8

OBJECTIVE

Design, fabricate, instal and test a pilot plant biogas purification system for use with an anaerobic digester operating on pig manure. The system should be capable of simply and economically removing HS from the biogas.

DESCRIPTION

Part A: Establish procedures for HS removal from dry gases using various scrubbing packings. One packing will be a mixture of iron oxide and wood chips. another will consist of iron oxide and saw dust as well as lime and cement. The third packing will consist of asbestos residues and iron oxide. The efficiency of each packing will be examined as well as its ease of regeneration by hot air passage over it.

Part B: Establish a process for HS oxidation under aqueous conditions. Construct and test a system consisting of two packed columns through which a solution of sodium carbonate will circulate. The first column will be used to purify the biogas while the second will be used to regenerate the solution.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1983-84	$22,000			$22,000
1984-85	$22,526			$44,526

REPORTS

No reports are available at this time.

STATUS AND COMMENT

Encouraging results have been obtained using the second packing material.

84/12/06

PROJECT DATA SHEET #	476	**PROGRAM IDENTIFICATION**	4.3.6.1 Biomass Conversion Technologies/ Biogas Production
TITLE	Comparaison of Five Biogas Reservoirs	**DURATION**	September 1983 - March 1985
CONTRACT #	01916-3-ER35	**COST**	$34,180
CONTRACTOR	Urgel Delisle et Associé St-Charles-sur-Richelieu Québec	**SPONSOR**	Agriculture Canada
PRINCIPAL INVESTIGATOR	M. Cournoyer	**SCIENTIFIC AUTHORITY**	R. Chagnon Centre de recherches de St-Jean Agriculture Canada Case postale 457 430 boul. Gouin St-Jean, Québec J3B 6Z8

OBJECTIVE

Construct, install and test five 30 m balloons for biogas storage. Each will be made from different materials to determine the best system. The cost as well as the advantages and disadvantages of each will then be evaluated.

DESCRIPTION

1. Design, construct and install the five balloons.
2. Connect the balloons to an anaerobic digester in order to evaluate their performance under normal operating conditions.
3. After six months of operation, each balloon will be subjected to pressure testing by gradually increasing the pressure to the design value.
4. After twelve months of operation, the pressure tests will be repeated and in this case the pressure will be increased up to the rupture pressure.
5. The balloons will be repaired and their long-term operation will be evaluated.
6. An economic and operational analysis of each prototype will be carried out.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1983-84	$13,000			$13,000
1984-85	$21,180			$34,180

REPORTS

No reports are presently available

STATUS AND COMMENT

The evaluation of the biogas balloons is in progress

84/11/29

PROJECT DATA SHEET # 480

TITLE High Solids Content Anaerobic Fermentation of Crop Residues

CONTRACT # 01916-3-ER31

CONTRACTOR University of British Columbia
Dept. of BioResource Engineering
Vancouver, British Columbia

PRINCIPAL INVESTIGATOR K.V. Lo

PROGRAM IDENTIFICATION 4.3.6.1
Biomass Conversion Technologies/
Biogas Production

DURATION April 1983 - March 1986

COST $185,000

SPONSOR Agriculture Canada

SCIENTIFIC AUTHORITY A.L. Moyls
Summerland Research Station
Summerland, British Columbia
V0H 1Z0
Tele.: (604) 494-7711

OBJECTIVE

To investigate the feasibility of high solids content (low moisture) anaerobic fermentation using crop residues mixed with dairy manure. To construct and field test a pilot scale digester suitable for high solids content anaerobic fermentation using crop residues with dairy manure.

DESCRIPTION

Phase I. Compare methane production rates from high solids anaerobic fermentation using lab scale digesters to conventional anaerobic digestion. Evaluate chemical factors such as ammonia, volatile acids, on the stability of high solids fermentation. Investigate feasibility of scaling up to a pilot scale dairy manure digester.

Phase II. Construct and test digesters to handle high solids compare designs with respect to materials handling problems and methane production. Construct pilot-scale digester, test and evaluate under different operating conditions.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1983-84 1984-85 1985-86	$ 17,000 $100,000 $ 68,000			$ 17,000 $117,000 $185,000

REPORTS

Interim report - expected September 1984.

STATUS AND COMMENT

Methane composition of gas from high solids fermentation is high (80-85%) compared to that from the filtered - low solids process (60%). There has not been any problem with NH or volatile acids stopping the reaction - the slurry has enough buffer to remain at pH = 6.8. Various stages of aerobic precomposting are being investigated and look promising.

84/12/06

PROJECT DATA SHEET # 482		**PROGRAM IDENTIFICATION**	4.3.6.1 Biomass Conversion Technologies/ Biogas Production
TITLE	Develop a Control System for a Methane Digester	**DURATION**	January 1984 - February 1986
CONTRACT #	01916-3-ER41	**COST**	$270,000
CONTRACTOR	Urgel Delisle et Associé St-Charles-sur-Richelieu Québec	**SPONSOR**	Agriculture Canada
PRINCIPAL INVESTIGATOR	M. Cournoyer	**SCIENTIFIC AUTHORITY**	R. Chagnon Centre de recherches de St-Jean Agriculture Canada Case postale 457 430 boul. Gouin St-Jean, Québec J3B 6Z8

OBJECTIVE

To construct and test a control system for use with on-farm anaerobic digesters.

DESCRIPTION

1. Define the control parameters and their inter-relationship.
2. Carry out a preliminary design of the control system.
3. Fabricate the control system and develop the necessary control software.
4. Check the control system during a 4 week intensive test using the Gasser digester.
5. Refine the system as necessary.
6. Evaluate the usefulness of the control system by permitting the farmer to operate it over a period of one year.
7. Evaluate the utility and degree of acceptance of the control system.
8. Evaluate the economics of the system.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1983-84	$ 2,000			$ 2,000
1984-85	$135,000			$137,000
1985-86	$133,000			$270,000

REPORTS

No reports are available at this time.

STATUS AND COMMENT

The control system is under construction.

84/12/06

PROJECT DATA SHEET #	176	**PROGRAM IDENTIFICATION**	4.3.6.2 Biomass Conversion Technologies/ Fermentation to Alcohol
TITLE	Liquid Fuel Production from Hemicellulose	**DURATION**	April 1981-March 1984
CONTRACT #	KL229-1-4116 (DSS80-00033) 23316-3-6151 (DSS83-00020) C-187	**COST**	$296,094
CONTRACTOR	Forintek Canada Corp. Eastern Forest Products Lab. 800 Montreal Road Ottawa, Ont. K1G 3Z5	**SPONSOR**	Energy, Mines & Resources
PRINCIPAL INVESTIGATOR	J.N. Saddler	**SCIENTIFIC AUTHORITY**	I. Veliky National Research Council Biological Sciences Sussex Drive Ottawa, Ont. K1A 0R6

OBJECTIVE

To prepare wood hemicellulose by water - extraction of steam exploded wood. To optimize the production of 2,3-butanediol by *Klebsiella pneumoniae*, *Trichoderma harzianum*. To optimize the production of butanol by *Clostridium acetobutylicum*. To assess the production of liquid fuels from wood residues.

DESCRIPTION

Previous research established optimum pretreatment conditions for the preparation of wood hemicellulose and demonstrated the efficient utilization of hemicellulose hydrolysates by *K. pneumoniae* and *C. acetobutylicum*. By using a combined hydrolysis and fermentation approach it should be possible to simplify the process by using wood hemicellulose without further treatment.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1981-82	$ 58,683			$ 58,683
1982-83	$ 95,665			$154,348
1983-84	$145,746			$296,094

REPORTS

Forintek Canada Corp., "Liquid Fuel Production from Hemicellulose," ENFOR project C-187, 1983.

STATUS AND COMMENT

PROJECT DATA SHEET # 236

TITLE Development of an Economical Fermentation Process for the Production of Organic Solvents from Biomass

CONTRACT # Strategic Grant

CONTRACTOR
Queen's University
Department of Microbiology
Kingston, Ontario
K7L 3N6

PRINCIPAL INVESTIGATOR A.M. Kropinski

PROGRAM IDENTIFICATION 4.3.6.2
Biomass Conversion Technologies/ Fermentation to Alcohol

DURATION November 1981 - November 1984

COST $185,000

SPONSOR Natural Sciences and Engineering Research Council

OBJECTIVE

Studies will concentrate on the development of genetically ameliorated bacterial strains which can ferment polymeric carbohydrates into alcohols and other useful compounds in unprecedented yields. The present limitation on solvent production with these organisms appears to be a result of end-product toxicity. Therefore, mutants displaying tolerance to fermentation end-product and insensitivity to intra- and extra-cellular phage and bacteriocins will be developed and exploited. This approach should afford solvents in much higher yields.

DESCRIPTION

The proposed research will concentrate on the development of genetically ameliorated bacterial strains which can tolerate high solvent concentrations. Three facets of the project and the suggested experimental approaches are outlined below.

1) The isolation of cellulose-, hemicellulose- and starch-degrading Clostridium strains and examination of culture supernatants for alcohols and other industrially useful chemicals.
2) The selection of mutant strains exhibiting increased tolerance to butanol.
3) The isolation of phage-resistant and nonbacteriocinogenic (or non-lysogenic) cultures.

Further specific studies will involve:

1) Selection of mutants with increased levels of starch/cellulose degrading enzymes. With the recent observation that C. acetobutylicum possesses carboxymethylcellulase and cellobiase activity this aspect of the project demands renewed attention. Whereas this organism is unable to degrade native cellulose it has been established that C. acetobutylicum can attack acid-swollen cellulose.
2) Selection of strains which produce solvents in different proportions.
3) The application of microbial genetics and recombinant DNA technology to strain improvement, initially involving the transfer of cellulose-degrading capacity by interspecies transformation using DNA from C. thermocellum or a related cellulose-degrading organism.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1981-82 1982-83 1983-84	$65,000 $60,000 $60,000			$ 65,000 $125,000 $185,000

REPORTS

STATUS AND COMMENT

84/12/01

PROJECT DATA SHEET # 248		**PROGRAM IDENTIFICATION**	4.3.6.2 Biomass Conversion Technologies/ Fermentation to Alcohol
TITLE	Production of Alcohol from Spent Sulfite Liquor Using NRC Pentose Fermenting Yeast	**DURATION**	October 1981 - October 1983
		COST	$275,456
CONTRACT #	Contribution Agreement CA155-1-0615/303B	**SPONSOR**	National Research Council PILP
CONTRACTOR	Tembec Inc. Temiscaming, Québec JOE 3RO	**SCIENTIFIC AUTHORITY**	H. Schneider National Research Council Ottawa, Ontario K1A OR6 Tele.: (613) 992-6512

OBJECTIVE

To develop a fermentation system using NRC xylose fermenter for the conversion of spent sulfite liquor to alcohol.

DESCRIPTION

1. Analysis of spent sulfite liquor (SSL) from soft and hardwoods to determine theoretical maximum alcohol obtainable.
2. Determine the amount of ethanol obtainable with brewer's yeast (for standard reference).
3. Determine amount of ethanol obtainable from strains of *P. tannophilus* from SSL.
4. Sugar analysis of the fermentation broth to determine species and amounts of sugars utilized.
5. Screen xylose fermenting yeasts.
6. Strain improvement by mutagenesis and selective crossing.
7. Optimization of the process.
8. Pilot scale operation.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1981-82	$ 14,114	$ 4,738		$ 18,852
1982-83	$ 42,342	$14,214		$ 75,408
1983-84	$129,000	$71,048		$275,456

REPORTS

STATUS AND COMMENT

Due to problem with pentose fermentation the project was terminated.

PROJECT DATA SHEET # 269

TITLE Development of Low-Cost Process for Ethanol Recovery

CONTRACTOR
Ontario Research Foundation
Sheridan Park Research Community
Mississauga, Ontario
L5K 1B3

PRINCIPAL INVESTIGATOR D.L. Mulholland

PROGRAM IDENTIFICATION
4.3.6.2
Biomass Conversion Technologies/ Fermentation to Alcohol

DURATION November 1982 - November 1983

COST $102,732

SPONSOR
Bioenergy Program
National Research Council
(Liquid Fuels Task)

SCIENTIFIC AUTHORITY
R.P. Overend
National Research Council
Montreal Road
Building R-105, Rm 135
Ottawa, Ontario
K1A OR6
Tel.: (613) 993-1342

OBJECTIVE

To determine the vapour-liquid equilibrium relationships of aqueous ethanol solutions in an efficient gas/liquid contactor and investigate the influence of selected solvents on this equilibrium. Subsequently, to determine the economic feasibility of utilizing such a process for low cost recovery of biomass-derived ethanol.

DESCRIPTION

Construct a bench scale (20 litre) gas/liquid contactor based on a energy efficient airlift principle.
Determine vapour-liquid equilibrium data for aqueous ethanol solutions at various temperatures, pressures and ethanol concentrations in the gas/liquid contactor.
Investigate the influence of selected organic solvents on these equilibrium relationships.
Evaluate an ethanol recovery system utilizing a selected solvent and the gas/liquid contactor for processing actual fermentation beer.
Correlate these results with those obtained on pure ethanol solutions.
Perform an economic feasibility study of such a process and compare to conventional distillation.
Give recommendations for future research or a strategy for commercialization.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1982-83 1983-84	$ 40,000 $ 62,732			$ 40,000 $102,732

REPORTS

Final Report available from NRC Publications: "Development of Low-Cost Process for Ethanol Recovery".

STATUS AND COMMENT

Project complete. Additional work to be carried out with other organic solvents
84/12/01

PROJECT DATA SHEET # 278

TITLE Comparison of Free & Immobilized Cell Fermentation to Fuel Alcohol

CONTRACT # 01916-2-EL14 (OSU82-00021)

CONTRACTOR
University of Western Ontario
Dept. of Chemical & Biochemical Eng.
Stevenson-Lawson Building
Room 101
London, Ontario
N6A 5E8

PRINCIPAL INVESTIGATOR
A. Margaritis
N. Kosaric

PROGRAM IDENTIFICATION
4.3.6.2
Biomass Conversion Technologies/
Fermentation to Alcohol

DURATION April 1982 - March 1984

COST $333,676

SPONSOR
Agriculture Canada
(Liquid Fuels Task)

SCIENTIFIC AUTHORITY
J.D. Miller
Chemistry and Biology
Research Institute
Research Branch
Agriculture Canada
Ottawa, Ontario
Tel.: (613) 995-3700

OBJECTIVE

To develop advanced systems for alcohol production.

DESCRIPTION

1. To screen micro-organisms (yeasts and bacteria) on their capability to ferment potato culls, cheese whey, Jerusalem artichokes, fodder beets and lignocellulosic substrates at a high rate and yield of alcohol production.
2. To develop scaled up immobilized and free cell continuous fermentation systems in parallel that are comparable on a rate capacity basis. Reactor volumes will be at least 10 L. Variations of the systems will be tested to optimize alcohol productivity.
3. To evaluate enhancement/treatment methods for stillage or fermentation byproducts of both immobilized and free cell systems to increase their value, reduce pollution load, facilitate materials handling, etc.
4. To perform an overall economic feasibility analysis of the two continuous systems at scales of production of 1 ML/a and 50 ML/a. The analysis will include engineering process designs, cost/equipment specifications and sensitivity to feedstock costs, fuel costs, etc. in sufficient detail to allow for a choice for eventual production facilities.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1982-83 1983-84	$148,676 $185,000			$148,676 $333,676

REPORTS

STATUS AND COMMENT

Completed May 1984. Final report expected September 1984. One aspect of the work is being investigated for patent protection 84/08/28

PROJECT DATA SHEET #	283	**PROGRAM IDENTIFICATION**	4.3.6.2 Biomass Conversion Technologies/ Fermentation to Alcohol
TITLE	Characterization of a Pilot Scale Adsorbed Cell Bioreactor for Ethanol Production	**DURATION**	December 1982 - December 1983
CONTRACT #	31155-2-2850 (0SU82-00346)	**COST**	$21,807
CONTRACTOR	Queen's University 131 Union Street Kingston, Ontario K7L 3N6	**SPONSOR**	Bioenergy Program National Research Council (Liquid Fuels Task)
PRINCIPAL INVESTIGATOR	A.J. Daugulis	**SCIENTIFIC AUTHORITY**	L. van den Berg National Research Council Rideau Falls Lab Ottawa, Ontario Tele.: (613) 992-3310

OBJECTIVE

To evaluate the technical feasibility of adsorbed cell bioreactors and determine the scale-up potential of such a reactor for ethanol production.

DESCRIPTION

To design and construct a column bioreactor 2 m in length which will utilize adsorbed whole cells for the continuous production of ethanol.
To install and integrate ancillary equipment used for operation of the reactor.
To operate the system at realistic substrate concentrations for extended periods of time.
To evaluate the performance of the system, propose possible design improvements, and assess the technical feasibility of the system for larger scale use.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1982-83 1983-84	$14,000 $ 7,807			$14,000 $21,807

REPORTS

DAUGULIS A.J., "Characterization of a Pilot Scale adsorbed cell bioreactor for ethanol production", Final Report

STATUS AND COMMENT

The study showed the potential of solid supports, the problems in scaling up and indicated ways of obviating these problems.

84/12/01

PROJECT DATA SHEET # 317

TITLE Assessment of the Production of Alcohol in Two Phase Systems

CONTRACT # 01843-1-EL13 (OSZ82-00041)

CONTRACTOR
Gemini Biochemical Research Ltd.
3650 - 21st Street N.E.
Calgary, Alberta
T2E 6V6

PRINCIPAL INVESTIGATOR
Ian Forrester
Tel.: (403) 285-8565

PROGRAM IDENTIFICATION
4.3.6.2
Biomass Conversion Technologies/ Fermentation to Alcohol

DURATION June 1982 - August 1983

COST $87,386

SPONSOR
Agriculture Canada
(Liquid Fuels Task)

SCIENTIFIC AUTHORITY
M. Stumborg
Agriculture Canada
Research Station
Box 1030
Swift Current, Saskatchewan
S9H 3X2
Tel.: (306) 773-4621

OBJECTIVE

DESCRIPTION

Phase I Determination of the ability of a second phase to partition various alcohol solutions from the aqueous phase from the standpoints of rate, efficiency or uptake and release, and energy requirements for regeneration.
Work shall be at lab scale using the following liquids for testing: (1) acetone, (2) butanol, (3) ethanol.
Phase II Examination of the interaction between the second phase and alcohol producing organisms during fermentation.
Work shall involve flask trials where active microbes are producing alcohol and other byproducts.
Parameters to be monitored include: (1) organism viability over time; (2) organism growth; (3) alcohol yields; (4) second phase viability and seperability; (5) second phase life expectancy; (6) economics and energetics of such a system.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1982-83	$69,386			$69,386
1983-84	$18,000			$87,386

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET #	332	**PROGRAM IDENTIFICATION**	4.3.6.2 Biomass Conversion Technologies/ Fermentation to Alcohol
TITLE	Process Engineering of Solvent Extraction Coupled Fermentations for Product Recovery	**DURATION**	November 1982 - November 1985
CONTRACT #	Strategic Grant	**COST**	$109,200
CONTRACTOR	Queen's University Dept. of Chemical Engineering Kingston, Ontario K7L 3N6	**SPONSOR**	Natural Sciences and Engineering Research Council
PRINCIPAL INVESTIGATOR	A.J. Daugulis		

OBJECTIVE

1. To increase the productivity of conventional fermentation bioreactor configurations. This will be achieved by minimizing end product inhibition and increasing the ease of product recovery. Products under investigation are ethanol and a polysaccharide, but application is envisaged to encompass other fermentation processes for producing industrial chemicals (e.g. acetone, butanol, butanediol).
2. To design, construct, operate and control continuous bioreactors which incorporate liquid-liquid extraction stages (internal or external). The extraction phase will be either hydrophilic or hydrophobic depending on the product to be recovered.
3. To estimate the important engineering parameters for understanding the limitations of the system and the design criteria for large scale equipment.
4. To transfer this information to relevant commercial enterprises.

DESCRIPTION

It is proposed that the conventional CSTR ethanol fermentation process be examined as a model system for integrating product separation with bioreactor design in an extraction coupled fermentation process. This will be done as follows:

1) A suitable extracting solvent must be found.
2) A preliminary evaluation of the solvent fermentation system must be performed. Continuous operation on a small scale and over a reasonable length of time (one week) will determine such things as: compatability of the solvent with microbial cells, possible detrimental solvent-cell interfacial phenomena, long term phase stability, stability of the liquid-liquid interface subject to continuous gas passage; and suitability of analytical techniques. By the end of this phase of the work, the most effective solvent, and preliminary process operating conditions, will have been identified.
3) The technical design of a continuous solvent extraction coupled fermentation process with continuous product recovery will be formulated. The design will incorporate an effective solvent contacting system, solvent-product removal system, and a continuous product recovery arrangement with solvent recycle. These aspects will be integrated into an overall design, and a suitable monitoring and control system will be devised. The performance characteristics and stability of the process will be evaluated by operating the system over a reasonable length of time (one to two weeks), and possible improvements made.
4) The techno-economic aspects of the process will be examined. It is important to investigate the suitability of the process to scale-up, the economic feasibility of the process relative to conventional ethanol fermentations, and the potential applicability of the process to other CSTR fermentations requiring continuous product removal.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1982-83	$35,000			$ 35,000
1983-84	$37,100			$ 72,100
1984-85	$37,100			$109,200

CONTINUED

REPORTS

STATUS AND COMMENT

Working in collabortion with Dr. D.H. Bone, Dr. R.H. Clark, Dept. of Chemical Eng. A.J.D.
84/12/06

PROJECT DATA SHEET #	338	**PROGRAM IDENTIFICATION**	4.3.6.2 Biomass Conversion Technologies/ Fermentation to Alcohol
TITLE	Development of Film Reactors Applicable to Ethanol Production	**DURATION**	November 1982 - November 1985
CONTRACT #	Strategic Grant	**COST**	$97,920
CONTRACTOR	Carleton University Dept. of Microbiology Ottawa, Ontario K1S 5B6	**SPONSOR**	Natural Sciences and Engineering Research Council
PRINCIPAL INVESTIGATOR	H. Yamazaki		

OBJECTIVE

I) To develop films onto which yeast or bacterial cells adsorb and form viable immobilized colonies, and

II) to develop fermentation processes using these films for production of microbial metabilites of practical importance such as ethanol.

DESCRIPTION

We have found that Saccharomyces cerevisiae cells adsorb to epichlorohydrin triethanolamine (ECTEOLA)-cotton cloth and develop ethanol producing colonies on the surface of the cloth (1). A cylindrical film fermentor was constructed by coiling a double layer of the cloth and a bronze screen and vertically placing the resulting coil into a column. Such a fermentor converts all sugars (14%) in the hydrolysate of Jerusalem artichoke tubers into ethanol with 90% of the theoretical yield after 6 h of fermentation. We noted that although unmodified cotton cloth initially binds yeast to a lesser extent, the yeast can eventually colonize on the cloth to the same extent as that on the modified cloth. We have then compared ethanol productivity by Saccharomyces cerevistiae, Kluyveromyces marxianus and Kluyveromyces fragilis colonized on unmodified cotton cloth. The S. cerevisiae film gave the highest productivity. A film fermentor suitable for scale-up was constructed, and ethanol productivity of the S. cerevisiae film was studied in this fermentor under three modes of operation: batch, circulated batch, and continuous flow. Circulation of the medium in batch fermentation gave the shortes completion time of fermentation, and accordingly the highest average ethanol productivity (2).

We are now extending applications of microbial films to other fermentation processes such as amino acid fermentation.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1982-83	$32,000			$32,000
1983-84	$33,920			$65,920
1984-85	$32,000			$97,920

REPORTS

LEUNG K.L., JOSHI S., and YAMAZAKI H., "Adsorption of Saccharomyces cerevisiae onto Cellulose and ECTEOLA-cellulose films for Ethanol Production", Enzyme Microb. Technol., 5, 181-184 (1983).

SONTAKKE S., and YAMAZAKI H., "Ethanol Production by Yeast Cells Colonized to Cotton Flannel", Proc. Fifth Bioenergy R&D Seminar (1984).

STATUS AND COMMENT

PROJECT DATA SHEET #	345
TITLE	On-Line Simulation/Control of Butanol-Hydrogen Biosynthesis
CONTRACT #	31926-3-0079 (ISU83-00081)
CONTRACTOR	McGill University 3480 University Street Montral, Québec H3A 2A7
PRINCIPAL INVESTIGATOR	B. Volesky
PROGRAM IDENTIFICATION	4.3.6.2 Biomass Conversion Technologies/ Fermentation to Alcohol
DURATION	June 1983 - May 1985
COST	$97,452
SPONSOR	Bioenergy Program National Research Council (Liquid Fuels Task)
SCIENTIFIC AUTHORITY	S. Hasnain Bioenergy Program National Research Council Building R-105, Rm 138 Ottawa, Ontario K1A OR6 Tele.: (613) 993-1342

OBJECTIVE

To develop and test a minicomputer-based system for simulation/control of a recycle stream for optimization of anaerobic biosynthesis of butanol-hydrogen from carbohydrates.

DESCRIPTION

- Minicomputer installation and adjustments required for the proposed application.
- Development and testing of the simulation-control minicomputer software package.
- Development of the Data Station-Minicomputer interface link.
- Minicomputer-Large Computer (existing) hierarchy link development.
- Development and installation of minicomputer control interfaces.
- Simulation-control program (software) testing and tuning.
- Testing of alternative metering devices (on-off control model with valves and/or pumps, proportional continuous control mode with pumps, etc.).
- Design and installation of the proportioning feed system for the simulated recycle stream make-up.
- Interfacing of the proportioning feed system with the minicomputer.
- Design of one or more sensors.
- Operation of the entire control system for the simulation of the recycle stream.
- Application of the system in adjusting the parameters and conditions in the bio-reactor which would enable the study of the biosynthesis system and its response to unconventional conditions of "continuous" solvent withdrawal and/or intermediate (precursor) metabolites concentrations adjustments and control.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1983-84	$42,375			$42,375
1984-85	$37,085			$79,460
1985-86	$17,992			$97,452

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 350		**PROGRAM IDENTIFICATION**	4.3.6.2 Biomass Conversion Technologies/ Fermentation to Alcohol
TITLE	Development of a Flexible Farm-Scale Fuel Alcohol Production System	**DURATION**	April 1981 - March 1985
CONTRACT #	01843-1-EL01 (OSZ81-00085)	**COST**	$227,500
CONTRACTOR	474706 Ontario Limited R.R. 3 Watford, Ontario N0M 2S0	**SPONSOR**	Agriculture Canada (Liquid Fuels Task)
PRINCIPAL INVESTIGATOR	G. Grewe	**SCIENTIFIC AUTHORITY**	E. Manolakis Engineering & Statistical Research Institute Research Branch Agriculture Canada Building #94 Central Experimental Farm Ottawa, Ontario K1A 0C6

OBJECTIVE

The major objective of the project is to develop a flexible farm scale fuel alcohol production system where a number of alternative process flow configurations will be examined. The system will provide a model for farmers or farm cooperatives to choose the most optimum process flow configuration for their particular situation and constraints.

DESCRIPTION

1. To develop a safe, efficient, inexpensive and multi-purpose distillation column that is appropriate for farm use and with an approximate capacity of 100-200 L/h of anhydrous ethanol.
2. To determine the optimum process operations (materials handling, pretreatment, hydrolysis, sterilization, microbial inoculation, fermentation and solid/liquid separation) as related to generically different feedstocks such as grains, sugar crops (stems and tubers), and starch tubers.
3. To evaluate and demonstrate the use and value of feeding stillage byproduct to animals (i.e., ruminant and monogastric).
4. To determine effective means for increasing the "shelf life" of stillage byproduct beyond the normal two days of safe storage, if possible.
5. To determine effective and environmentally acceptable means of reducing and/or disposing of waste water or thin stillage.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1981-82	$ 20,000			$ 20,000
1982-83	$103,500			$123,500
1983-84	$ 60,000			$183,500
1984-85	$ 44,000			$227,500

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 351

TITLE Fuel Ethanol Dehydration

CONTRACT # 01843-1-EL09 (DSZ81-00135)

CONTRACTOR
Wellington Engineering Ltd.
29 Hickory Street
Guelph, Ontario
N1G 2X2

PRINCIPAL INVESTIGATOR L. Otten

PROGRAM IDENTIFICATION
4.3.6.2
Biomass Conversion Technologies/
Fermentation to Alcohol

DURATION April 1981 - March 1984

COST $87,000

SPONSOR
Agriculture Canada
(Liquid Fuels Task)

SCIENTIFIC AUTHORITY
E. Manolakis
Engineering & Statistical
Research Institute
Research Branch
Agriculture Canada
Building #94
Central Experimental Farm
Ottawa, Ontario
K1A 0C6

OBJECTIVE

To produce novel dehydration systems for farm produced alcohol.

DESCRIPTION

1. The contractor will perform laboratory experiments to evaluate the dehydration properties of a number of organic and inorganic dessicants. Emphasis is to be placed on agricultural materials (e.g. dried cracked corn). Approximately five to ten inorganic dessicants will be examined depending on time available and conclusions drawn from a literature review. Specific energy to regenerate the dessicants and design parameters will be determined. Laboratory analysis will also include optimum corn dryness required and the suitability of cracked corn with absorbed water as a fermentation substrate.
2. The contractor will design one or more systems based on analysis of laboratory work and as described in the proposal.
3. The chosen system or systems will be constructed, installed and tested at a farm fuel alcohol plant. It is anticipated that the system will be designed for a rated capacity of 20-25L/h.
4. The system as demonstrated will be analysed in terms of cost and energy requirements. In addition, the contractor will perform a projected cost analysis for larger systems including 500,000 L/a (e.g. 150-200 L/h) and 5,000,000 L/a (e.g. 700-800 L/h).

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1981-82	$ 5,000			$ 5,000
1982-83	$ 62,000			$ 67,000
1983-84	$ 20,000			$ 87,000

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 352

TITLE
Development of a System of
Automatically Denaturing
Ethanol Destined
for Fuel Purposes

CONTRACT # 01843-1-EL03/1 (DSZ82-00024)

CONTRACTOR
Manitoba Research Council
Canadian Food Products
Development Centre
810 Phillips Street
Portage la Prairie, Manitoba
R1N 3J9

PRINCIPAL INVESTIGATOR
J. Hilliard
Tel.: (204) 857-7861

PROGRAM IDENTIFICATION
4.3.6.2
Biomass Conversion Technologies/
Fermentation to Alcohol

DURATION April 1982 - March 1984

COST $46,000

SPONSOR
Agriculture Canada
(Liquid Fuels Task)

SCIENTIFIC AUTHORITY
E. Manolakis
Engineering & Statistical
Research Institute
Research Branch
Agriculture Canada
Building #94
Central Experimental Farm
Ottawa, Ontario K1A 0C6

OBJECTIVE

A method or system that automatically denatures ethanol destined for fuel purposes is sought.

DESCRIPTION

The method or system must be tamper-proof and/or be an inherent component of the production system. The denaturing system must not be able to be bypassed. It is preferred that the ethanol/water separation system cannot operate unless the denaturing system is functioning. The ethanol must be denatured before it reaches the receiver.

A method or methods applicable to various separation systems such as distillation, membrane separation, solvent extraction, freeze concentration, molecular seive, etc. should be considered.

It is intended to develop a method or system that will render the alcohol exempt from the requirements needed for beverage alcohol. The contractor must therefore work closely with the various regultory and legislative entities that control the production of alcohol in order to meet this requirement.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1982-83 1983-84	$ 46,000 0			$ 46,000 $ 46,000

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 354

TITLE Ethanol from Cellulosics Pilot Plant

CONTRACTOR
Canertech Inc.
1003 - 213 Notre Dame
Winnipeg, Manitoba
R3B 1N3

PRINCIPAL INVESTIGATOR
H.E. Duckworth
Tel.: (204) 949-1160

PROGRAM IDENTIFICATION 4.3.6.2 Biomass Conversion Technologies/ Fermentation to Alcohol

DURATION April 1982 - March 1988

COST $565,000

SPONSOR Energy, Mines & Resources

SCIENTIFIC AUTHORITY
A. Dolenko
Renewable Energy Division
Energy, Mines & Resources
460 O'Connor Street
Ottawa, Ontario
K1A OE4
Tel.: (613) 995-9447

OBJECTIVE

To formulate a strategy for the implementation of a program on the development and demonstration of ethanol from cellulosics at the pilot plant scale.

DESCRIPTION

Phase I Implementation study
Phase II Construction of pilot plant
Phase III Operation of the pilot plant
Phase I will better define engineering parameters (HF loading, temperature, heat and mass transfer characteristics, secondary hydrolysis conditions), will optimize process conditions, will develop a variety of systems and a complete conceptual process design that will allow for a preliminary evaluation/analysis of the technical and economic feasibility.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1982-83 1983-84	$200,000 $365,000			$200,000 $565,000

REPORTS

"Implementation Study for Ethanol from Cellulose Program." March 1982

STATUS AND COMMENT

Phase I completed. Phase II will start after Treasury Board approval. A.D.
84/12/06

PROJECT DATA SHEET #	384
TITLE	Bioconversion of Agricultural Waste Residues into Fuel-Grade Ethanol
CONTRACT #	Research Agreement Program
CONTRACTOR	University of Waterloo Faculty of Engineering Waterloo, Ontario N2L 3G1
PRINCIPAL INVESTIGATOR	M. Moo-Young Tele.: (519) 885-1211 Ext. 3919
PROGRAM IDENTIFICATION	4.3.6.2 Biomass Conversion Technologies/ Fermentation to Alcohol
DURATION	April 1983 - March 1984
COST	$30,500
SPONSOR	Energy Mines & Resources

OBJECTIVE

To develop and test a prototype unit to utilize forestry and agricultural crop residues to produce fuel-grade ethanol using innovative developments of a three-stage process involving hydrolysis, fermentation and distillation. To demonstrate the socio-economic importance of production of a clean-burning liquid fuel from abundant renewable biomass resources which occur universally as surplus or waste, with concurrent abatement of environmental pollution normally caused by the waste residues, reduction of disposal costs, and/or reduction in reliance on traditional fossil fuel.

DESCRIPTION

First Stage of the proposed process will involve acid and/or enzymatic hydrolysis. The use of chemical catalysts will also be considered with the acid hydrolysis. The fermentation stage will be based on three strategies to be considered: conventional yeast mono-culture; innovative dual-culture in a single mixed fermentor or in two sequential fermentors with pure cultures; innovative immobilized whole-cell packed-bed reactor.
The second potential innovation would enable utilization of both the hexoses and the pentoses produced in the hydrolysis stage. The distillation stage would be based on a conventional multi-tray column to produce 95% EtOH. Preliminary economic evaluations would be carried out based on known prior-art and lab scale experiments to test potential technological innovations. Plant capacities required for breakeven and profit would be determined as well as the effect of the date of plant testing of the most attractive process would be carried out and computer programs would be developed to identify the commercial feasibility for various scenarios in both developed and Third world countries.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$30,500			$30,500

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET #	456	**PROGRAM IDENTIFICATION**	4.3.6.2 Biomass Conversion Technologies/ Fermentation to Alcohol
TITLE	Development of Protein Recovery Techniques for Fuel alcohol Production	**DURATION**	April 1982 - March 1985
CONTRACT #	E1037	**COST**	$418,000
CONTRACTOR	University of Saskatchewan POS Pilot Plant Corp. Saskatoon, Saskatchewan S7N 2R4	**SPONSOR**	Agriculture Canada
PRINCIPAL INVESTIGATOR	D. Jones	**SCIENTIFIC AUTHORITY**	G. Knipfel Swift Current Research Station Research Branch Agriculture Canada P.O. Box 1030 Swift Current, Saskatchewan S9H 3X3 Tele.: (306) 773-4621

OBJECTIVE

To develop methods for the extraction of protein form barley, triticale, rye, oats, field beans, and faba beans, and from their residues following fuel alcohol fermentation . Phase 1 (6 months): literature review; Phase 2 (4 months): lab investigations. Phase 3 (6 months): lab pilot scale of selected methods development and testing of dry processing methods. Phase 4 (6 months): same as above for wet processing methods. Phase 5 (6 months): full pilot scale of selected methods with fermentation of starch streams and production of post fermentation residues. Phase 6 (9 months): characterization of protein concentrates and preliminary assessment of market possibilities. Phase 7 (4 months): lab investigation of methods identified in Phase 1 applied to post fermentation residues from Phase 5. Phase 8 (6 months): development and evaluation of processing methods for post fermentation residues including pilot scale up. Phase 9 (9 months): characterization of materials produced in Phase 8 and preliminary assessment of market possibilities.

DESCRIPTION

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1982-83	$ 39,000			$ 39,000
1983-84	$280,000			$319,000
1984-85	$ 99,000			$418,000

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 459

TITLE Feeding Byproduct of Ethanol Production from Corn - Phase 2

CONTRACT # 24ST.01916-3-EL24

CONTRACTOR
University of Guelph
Dept. of Animal & Poultry Science
Guelph, Ontario
N1G 2W1

PRINCIPAL INVESTIGATOR D.N. Mowat

PROGRAM IDENTIFICATION 4.3.6.2
Biomass Conversion Technologies/ Fermentation to Alcohol

DURATION April 1983 - May 1985

COST $92,000

SPONSOR Agriculture Canada

SCIENTIFIC AUTHORITY
P. Van Die
Head, Energy Section
Research Branch
Agriculture Canada
Ottawa, Ontario
K1A 0C6
Tele.: (613) 995-9671

OBJECTIVE

Carry-on work of Contract EL08 to evaluate silage separator unit III; to assess keeping qualities of silage in horizontal Ag-bag silos; to further investigate cattle feedlot performance of separated stover with stillage (or wet corn gluten feed); and to further assess the keeping quality of stillage during warm weather.

DESCRIPTION

1. Summer '83. Planning and organizing arrangements for stillage or wet corn gluten feed, feeding trials, harvesting and storage.
2. Fall '83. Harvest regular (65% m.c.) and mature (50% m.c.) corn silage. Cattle purchase.
3. Win/Spring '84. Feedlot trials (80 heifer calves) to compare regular corn silage plus soybean meal vs. ensiled separated stover plus stillage (or wet corn gluten feed). Evaluation of Separation Unit III, preservation of mature corn silage and of stillage in warm weather.

(Note: The costs of developing Unit III, the feed rations, and the feedlot are funded from other governments (i.e. OMAF) and agencies).

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1983-84	$24,000			$24,000
1984-85	$59,000			$92,000

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET #	462	**PROGRAM IDENTIFICATION**	4.3.6.2 Biomass Conversion Technologies/ Fermentation to Alcohol
TITLE	Biochemical Studies on Cellobiose Metabolism by Yeasts	**DURATION**	October 1983 - October 1985
CONTRACT #	34SZ.01916-3-EL20	**COST**	$116,000
CONTRACTOR	Labatt Brewing Co. 150 Simcoe Street London, Ontario N6A 4M3	**SPONSOR**	Agriculture Canada
PRINCIPAL INVESTIGATOR	G.G Stewart	**SCIENTIFIC AUTHORITY**	J.D. Miller Chemistry & Biology Research Institute Agriculture Canada Ottawa, Ontario K1A OC6 Tele.: (613) 995-3700

OBJECTIVE

To genetically manipulate Saccharomyces so that it can metabolize and convert cellobiose and other low molecular weight polymers of glucose directly into ethanol without prior hydrolysis.

DESCRIPTION

1. 7 or more yeasts compared for ability to produce -glucosidase (cellobiase) intracellularly or extracellularly.
2. Further physiology studies on selected yeasts and purification of their cellobiase systems.
3. Characterize cellobiase systems.
4. Using radiolabelled antibodies against purified -glucosidases, immunologic screening techniques for subsequent identification of transformed or fused products of Saccharimyces able to produce the cellobiase system.
5. Genetically manipulate cellobiase gene system into Saccharomyces through fusion or transformation and screen using the technique in 4 above.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1983-84	$33,000			$ 33,000
1984-85	$83,000			$116,000

REPORTS

STATUS AND COMMENT

On-going

PROJECT DATA SHEET #	467	**PROGRAM IDENTIFICATION**	4.3.6.2 Biomass Conversion Technologies/ Fermentation Alcohol
TITLE	Pilot Scale Byproduct Protein Recovery and Hydrolysis of Carbohydrate Residue	**DURATION**	April 1983 - March 1985
CONTRACT #	E2117 EL21	**COST**	$195,000
CONTRACTOR	University of Saskatchewan POS Pilot Plant Corp. Saskatoon, Saskatchewan S7N 2R4	**SPONSOR**	Agriculture Canada
PRINCIPAL INVESTIGATOR	S. McCurdy	**SCIENTIFIC AUTHORITY**	G. Knipfel Swift Current Research Station Research Branch Agriculture Canada P.O. Box 1030 Swift Current, Saskatchewan S9H 3X3 Tele : (306) 773-4621

OBJECTIVE

Based on current project findings (EL15) select 5 crops or commodities (e.g. corn, barley, alfalfa, fababeans, grain screenings) and develop processes for the recovery of value added protein as food or feed and the hydrolysis/fermentation of starch, hemicellulose and cellulose residues. Evaluate the economics of the processes in an industrial context and also as an on-farm community scale option.

DESCRIPTION

POS to obtain raw material. Wet extraction of protein from all 5 commodities. Dry extraction of faba beans only. Wet carbohydrate residues spray dried for transport to SLT. SLT to hydrolyse carbohydrates in their acid catalysed plug-flow reactor, analyse hydrolysates and determine fermentability. residues from fermentation shipped back to POS for further protein recovery by wet and dry extraction techniques. The workplan for Process 2 (in the proposal) is not clear re. the materials that will undergo SLT hydrolysis without prior protein recovery.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1983-84	$ 65,000			$ 65,000
1984-85	$130,000			$195,000

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 469

TITLE Further Development and Testing of Technology for Fibre Fractions from Commercial Corn Milling

CONTRACT # 01916-3-EL26 (DSZ83-00097)

CONTRACTOR
St. Lawrence Technologies Ltd.
50 Elmwood Avenue South
Mississauga, Ontario
L5G 3J7

PRINCIPAL INVESTIGATOR P. Assarsson

PROGRAM IDENTIFICATION 4.3.6.2 Biomass Conversion Technologies/ Fermentation to Alcohol

DURATION January 1984 - January 1986

COST $269,230

SPONSOR Agriculture Canada

SCIENTIFIC AUTHORITY
E. Manolakis
Engeering & Statistical
Research Branch
Agriculture Canada
Engeering Bldg #94
C.E. Farm
Ottawa, Ontario
K1A 0C6
Tele.: (613) 995-9671

OBJECTIVE

1. To further develop the technology for the acid hydrolysis of agricultural crop residues which are mixed carbohydrates but primarily cellulosic in nature such as Jerusalem Artichoke tops, corn stover, barley straw, and commercial wood wastes or residues, primarily aspen chips, using the hydrolysis process of St. Lawrence Technologies Ltd.
2. to further develop the use of the St. Lawrence reactor for the main hydrolysis of autohydrolysed corn stover and aspen chips, including feeding of high consistency slurries.
3. to further develop the technology for the hydrolysis of the coarse fibre fraction of the wet milling of corn using the hydrolysis processes of St. Lawrence Technologies Ltd.
4. to further develop the technology for the hydrolysis of fibrous residues from the dry milling of corn.
5. to analyze the sugars in the above hydrolysates and test their fermentability to ethanol.
6. to evaluate the economy of the SLT processing systems as applied to agricultural crop residues in terms of their capability to contribute to liquid fuel supply.
7. to evaluate the economy of the SLT processing systems in terms of their ability to contribute to the value of the corn processing systems and to liquid fuel supply.
8. to evaluate the economics of on-farm dry milling of corn and its conversion to ethanol from information derived above.
9. to evaluate the possibility of on-farm and farm-community processing of agricultural crop residues using the SLT processing systems and their conversion to ethanol.

CONTINUED

DESCRIPTION

1. The SLT plug flow reactor will be used to hydrolyse Jerusalem artichoke tops, barley straw, straw and corn stover. Some of the auxiliary equipment including the feeding mechanism, will require modification to achieve high consistency cellulosic slurries (18-25%) which can be fed to the hydrolyzer. Subdivision by means of a hammer mill or other such device will be necessary for some of these materials. At least two stages will be required for the hydrolysis of cellulosic materials. The hemicelluloses will be hydrolysed in the prehydrolysis first stage and the separated fibrous residues hydrolysed on a second stage. The separation of the sugars from the fibres between stages may be done on a filter or a centrifuge may be needed for good economy. The optimum operating conditions for each feedstock will be determined.
2. Autohydrolysed corn stover and aspen chips will be obtained. These materials will be washed with water to recover the hemicellulose prehydrolyzate and the washed fibres will be formed into a concentrated slurry (18-25% consistency) with water containing acid catalyst. The slurry will be hydrolysed in the SLT reactor. A series of runs through the SLT reactor will be made to determine optimal operating conditions.
3. The prehydrolyzate and hydrolyzate solution will be analysed in the SLT analytical facilities to determine the type and quantity of the various sugars present, including dimers and trimers and other organic materials present. The hydrolyzates will be tested for fermentability by ordinary yeast in shake flasks.
4. Mass and energy balance will be performed on the above systems as the data is gathered.
5. The data obtained will be used to carry out economic analyses and will evaluate the possibility of applying the SLT reactor for the on-farm and farm-community processing of the above materials, for ethanol production.
6. If promising results are obtained for the hydrolysis of the materials in 1) and/or 2) above the fibrous residues will be processed in the SLT reactor. At least two stage will be required for the hydrolysis of the fibrous residues. In the first stage conditions will be establish for the acid hydrolysis of the starch and the hemicellulose components of the fibre fraction. Assuming that both can be hydrolysed at the same time, the hydrolysis conditions may or may not be optimal. Following hemicellulose hydrolysis, the cellulose will be separated from the sugar syrup, either by filtration or by centrifuge. The cellulose will then be fed to the reactor and hydrolyzed. It may be desirable to conduct this hydrolysis in several stages or to recycle unhydrolyzed celluloses to get good yeilds of sugars.
7. When the study of the coarse fibre fraciton of the wet milling operation is complete the corresponding fibre fractions from dry milling operations will be obtained and studies will be conducted to establish the best procedures for their hydrolysis using the SLT reactor.
8. The hydrolyzates form 6) and 7) above will be analyzed for the different sugars and tested for fermentability as described in 3) above.
9. Economic analyses of the systems in 6) and 7) above will be carried out. An economic analysis of on-farm dry milling of corn and its conversion to ethanol will be included.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1983-84 1984-85 1985-86	$ 22,000 $135,000 $112,230			$ 22,000 $157,000 $269,230

REPORTS

STATUS AND COMMENT

Progress to date involves delivery of a new continuous plug flow reactor to process the high solids cellulose slurry, its installation and delivery and installation of a high pressure boiler to deliver process heat. First few runs on steam exploded material (aspen wood) have been initiated. Other feedbacks to follow as per statement of work.

84/12/05

PROJECT DATA SHEET #	470	**PROGRAM IDENTIFICATION**	4.3.6.2 Biomass Conversion Technologies/ Fermentation to Alcohol
TITLE	Microprocessor Control of Bioethanol Fuel Fermentation	**DURATION**	April 1983 - March 1985
CONTRACT #	E2208 EL32	**COST**	$35,000
CONTRACTOR	University of Guelph Dept. of Botany and Genetics Dept. of Agriculture Engineering Guelph, Ontario N1G 2W1	**SPONSOR**	Agriculture Canada
PRINCIPAL INVESTIGATOR	R.E. Subden	**SCIENTIFIC AUTHORITY**	E. Manolakis Engineering & Statistical Research Branch Agriculture Canada Engeering Bldg #94 C.E. Farm Ottawa, Ontario K1A OC6 Tele.: (613) 995-9671

OBJECTIVE

To develop a microprocessor/instrumentation control system for fermentation of ethanol to cut production costs and maintain quality control.

DESCRIPTION

Year 1
1a. Evaluation of sensors, microprocessors and computer systems.
1b. Batch fermentations with S. cerevisiae and Z. mobilis moniotred with lab and instrumental analysis.
1c. Modify fermentors to accept sensors as they are selected.
1d. Batch fermentations and monitor metabolite prod'n from microbial contaminants and growth kinetics.
Year 2
2a. Modify batch fermentations into continuous fermentation, add microbial contaminants and monitor fermentation parameters via the sensors. New organisms to be used to determine the versatility of the system.
2b. Computer program modified to accommodate continuous mode and to test parameter changes that will select against microbial contamination proliferation.
2c. Cost analysis to determine minimum instrumentation.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1983-84	$ 5,000			$ 5,000
1984-85	$30,000			$35,000

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 173

TITLE Development of Analytical Methodology for Biomass Gasification Products

CONTRACT # KL229-1-4114 (OSS81-00051)
C-172

CONTRACTOR Techwest Enterprises Ltd.,
3650 Wesbrook Crescent
Vancouver, B.C. V6S 2L2

PRINCIPAL INVESTIGATOR G. Esplin

PROGRAM IDENTIFICATION 4.3.6.3
Biomass Conversion Technologies/
Low Joule Value Gasification

DURATION April 1981 - July 1984

COST $275,539

SPONSOR Energy, Mines and Resources

SCIENTIFIC AUTHORITY D.P.C. Fung
CANMET
Energy, Mines & Resources
555 Booth Street
Ottawa, Ontario.
K1A OG1
Tel.: (613) 995-6401

OBJECTIVE

To develop a standard procedure for the collection, separation and analysis of "Dirty gas" from biomass gasification so that results from various contractors can be compared meaningfully.

DESCRIPTION

The following are to be determined:

1. Volume rate of the "dirty gas" which is hot (200-400C) and contains non-condensable gases, tarry liquid and solid particles;
2. Mass of gas, liquid and solid;
3. Quantity of the liquid fraction with special emphasis on the chemical constituents (qualitative analysis) and energy of the tarry materials;
4. Chemical composition and energy content of the gas, liquid and solid.

The principal investigator will visit concerned contractors on a fact-finding mission before the development work. The developed methodology should be simple and versatile for both pilot plant scale (gasification at a rate of 80 kg of biomass per hour) and laboratory scale (1 kg of biomass per hour). Preferably only conventional instruments such as gas chromatography, GC-MS spectrometry and gel permeation chromatography should be applied in this methodology.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1981-82	$110,280			$110,280
1982-83	$126,299			$236,579
1983-84	$ 38,960			$275,539

REPORTS

1. A Workbook for Biomass Gasifier Sampling and Analysis was available in September 1983.
2. A Manual for Evaluating Biomass Gasifier was available in July 1984.

STATUS AND COMMENT

This contract work was completed in July 1984. D.P.C.F.

84/12/04

PROJECT DATA SHEET # 307		**PROGRAM IDENTIFICATION**	4.3.6.3 Biomass Conversion Technologies/ Low Joule Gasification
TITLE	Development, Operation and Evaluation of a Small Scale Gasification/Water Heating System	**DURATION**	February 1982 - May 1984
		COST	$61,000
CONTRACT #	01843-1-ER13 (0SZ81-00131)	**SPONSOR**	Agriculture Canada
CONTRACTOR	Biomass Combustion Ltd. Canning, Nova Scotia B0P 1H0	**SCIENTIFIC AUTHORITY**	D. Marshall Engineering & Statistical Research Institute Research Branch Agriculture Canada Ottawa, Ontario K1A 0C6 Tel.: (613) 995-9671
PRINCIPAL INVESTIGATOR	J. Peill		

OBJECTIVE

DESCRIPTION

The contractor shall develop, operate and evaluate a packaged straw combustion system using conventional bales in a burner consisting of a combustion gasification chamber combined with a gas/water heat exchanger in one shell. The overall performance will be evaluated by the contractor. Combustion efficiency tests, hourly maximum outputs and emission tests shall be performed by a suitable consultant.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1981-82	$13,651			$13,651
1982-83	$30,349			$44,000
1983-84	$15,000			$59,000
1984-85	$ 2,000			$61,000

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 478

TITLE Development and Evaluation of a Small Scale Gasifier System for Utilizing Farm Wastes

CONTRACT # 01916-3-ER38(OSG83-00130)

CONTRACTOR Mayer and Poer Corp. Inc.
Winnipeg, Manitoba

PRINCIPAL INVESTIGATOR E. Mayer

PROGRAM IDENTIFICATION 4.3.6.3
Biomass Conversion Technologies/ Low Joule Gasification

DURATION November 1983 - November 1984

COST $76,800

SPONSOR Agriculture Canada

SCIENTIFIC AUTHORITY
D. Campbell
Agriculture Canada
Box 1030
Swift Current, Saskatchewan
S9H 3X2
Tele.: (306) 773-4621

OBJECTIVE

To optimize the operation and monitor the performance of a prototype gasifier using locally available fuels: cubed wood wastes, flax straw, sunflower hulls and corn stalks (PHASE I). To evaluate and utilize the gas in direct-fired systems such as boilers and grain dryers and to develop a clean-up system comprised of: a cyclone separator; a scrubber and a feed stock filter bed or bag filters, as required, to clean-up the gas for use in dual fuel engines (PHASE II). Phase II is not included in this contract.

DESCRIPTION

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1983-84	$30,000			$30,000
1984-85	$46,800			$76,800

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 188

TITLE Development and Demonstration of a Pressurized Oxygen Fluidized Bed for Wood Gasification

CONTRACTOR
Biosyn Inc.
Suite 1806
1080 Beaver Hall Hill
Montreal, Quebec
H2Z 1S8

PRINCIPAL INVESTIGATOR
J. Gravelle
Project Manager

PROGRAM IDENTIFICATION
4.3.6.4
Biomass Conversion Technologies/
Medium Joule Gasification

DURATION April 1981 - March 1984

COST $21,660,000

SPONSOR
Energy, Mines & Resources
(Liquid Fuels Task)

SCIENTIFIC AUTHORITY
Allan Dolenko
Energy, Mines & Resources
460 O'Connor Street
Ottawa, Ontairo
K1A OE4
(613) 995-9447 ext. 300

OBJECTIVE

To design, construct and develop a fluidized bed with a capacity of 5-10 tonnes of oven-dry wood/hour using oxygen as the combustive gas and operating over a pressure range of 1 to 20 atm for the production of synthesis gas from biomass.

DESCRIPTION

This program is intended to demonstrate at a pre-commercial, pilot scale a pressurized oxygen fluidized-bed gasifier for producing synthetic gas which can be used in the manufacture of methanol.

Expected outputs: An assessment of the technology and its economic feasibility for incorporation into a methanol production plant. Results obtained will permit extrapolation of the data for the design, construction and operation of large-scale gasification plants.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
Year 1	$ 325,000			$ 325,000
Year 2	$1,625,000	$9,800,000 (capital)		$11,750,000
Year 3	$3,880,000	$6,030,000 (capital)		$21,660,000

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 257		**PROGRAM IDENTIFICATION**	4.3.6.4 Biomass Conversion Technologies/ Medium Joule Gasification
TITLE	Molten Salt Technology for Wood to Syngas Conversion	**DURATION**	May 1982 - May 1984
CONTRACT #	31155-1-2687 (DSX82-00012) 31155-1-2687 (DSX82-00226)	**COST**	$223,564
CONTRACTOR	SNC Inc. 1 Complexe Desjardins Case Postale 10 Succursale Desjardins Montréal, Québec H5B 1C8	**SPONSOR**	Bioenergy Program National Research Council
		SCIENTIFIC AUTHORITY	R.P. Overend National Research Council Montreal Road Building R-105, Rm 135 Ottawa, Ontario K1A 0R6 Tele.: (613) 993-1342

OBJECTIVE

To evaluate a process involving the use of molten salt technology in the conversion of wood to synthetic gas.
The work is to re-design a bench-scale molten salt bath gasification unit by incorporating or modifying those characteristics of the design which are necessary to allow the use of wood of appropriate particle size as the organic feedstock and operation in the combustion or gasification mode.

DESCRIPTION

Phase I
Estimates of the cost and proposed performance specifications are being prepared. Support of the feasibility of carrying out such studies will form part of the report.

Phase II Task I
Fourteen individual gasification tests will be carried out on samples of wood provided by NRC. During the tests the off-gas will be analyzed continuously for carbon monoxide, carbon dioxide, and hydrogen; and periodically for methane, nitrogen and water. During each test a sample of particulates in the gas will be analyzed for tar and sodium content, and a sample of the molten salt will be analysed for combustible carbon and selected melt components. Corrosion rate data will be obtained using an alloy believed to be suitable for construction of molten salt wood gasification vessels. Engineering analyses will be performed to establish test conditions, correlate test results, predict the effects fo higher pressure operation and provide input to plant design studies.

Task II
- Conceptual designs of process schemes such as the low pressure electric heating mode and the low pressure electrolytic oxygen mode.
- Costing of the conceptual process schemes to $/GH for 95% hydrogen, methanol plant feed and fuel/reducing gas.
- Technology assessment (preliminary cost-benefit, manufacture of other products, use of other wood-based feedstocks, problems in scaling ups, patent situation and requirements for further research and development).

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1982-83	$ 31,200			$ 31,200
1983-84	$171,144			$202,344
1984-85	$ 21,220			$223,564

CONTINUED

REPORTS

MOFFATT J.M., "Molten Salt Technology for Wood to Syngas Conversion - Phase 2, Task 1, Test Summary Report"

MOFFATT J.M. and ANAND U.S., "Molten Salt Technology for Wood to Syngas Conversion - Phase 2, Task 2, Final Report Technical Economic Assessment".

These reports are available through CISTI.

STATUS AND COMMENT

PROJECT DATA SHEET # 330

TITLE Development of a Simple
Dual-Bed Fluidized Gasifier
forBiomass & other
Pyrolyzable Wastes

CONTRACT # Strategic Grant

CONTRACTOR University of Western Ontario
London, Ontario
N6A 5B8

PRINCIPAL INVESTIGATOR Jan M. Beeckmans
Dept. of Chemical Eng.

PROGRAM IDENTIFICATION 4.3.6.4
Biomass Conversion Technologies/
Medium Joule Gasification

DURATION November 1981 - November 1984

COST $63,400

SPONSOR Natural Sciences and
Engineering Research Council

OBJECTIVE

The objective of the project is the development of a simple dual-chamber fluidized bed system for gasifying biomass or garbage to produce a gas having a calorific value in the range of 10-20 MJ/N-m. In a dual-bed gasifier hot sand is circulated between an air-fluidized regenerator, in which char is burnt and the sand is heated to approximately 900C, and a steam-fluidized gasifier, in which the organic material is pyrolyzed and gasified. Since the gases from the two beds do not mix, the gasifier gas is essentially nitrogen free, and it contains relatively little carbon dioxide. On the other hand, the waste gases from the combustor are composed primarily of nitrogen, carbon dioxide and water vapour. They are, in fact, similar to conventional combustion gases; however, char is such a clean fuel that it produces fewer gaseous and particulate pollutants than from combustion of the biomass in a conventional boiler.
The main advantage of dual-bed gasification is that it produces a gas in the medium calorific value range, without the necessity for using pure oxygen.

DESCRIPTION

It is proposed here to investigate the possibility of using a single, internally partitioned bed of cylindrical geometry.
The motive power for circulation of solids in this system is provided by the difference in bulk density between solids in the combustion section, which are fluidized at relatively high velocity, and solids in the gasification section, where the fluidizing velocity would be much smaller.
In Phase I, solids circulation patterns and gas mixing will be studied in a "cold" model, and a suitable design will be developed. In phase 2, a small prototype gasifier will be constructed and operated using sawdust, wood chips and other biomass.
Solids circulation will be studied by adding separable tracer particles to one of the fluidized beds, and noting their rate of appearance in the other bed. Gas mixing will similarly be studied by adding ammonia gas to the fluidizing air under one bed, and determining its concentration in the exhaust gas from the other bed. Variables to be studied include the fluidization velocity in both beds, the mean size of the solids, the height of the beds, and size and location of the orifices in the baffle separating the beds. The designs will be based on a scale of 2 tonnes/day of biomass (approximately 80 kg/h).
The cold model studies will not be restricted to purely empirical observations, and every effort will be made to understand and explain the results in terms of the underlying physical phenomena. These include the distribution of pressure with height on both sides of the vertical baffle and the mechanics of flow of fluidized solids across a submerged orifice under a small pressure gradient. A quantitative & qualitative understanding of these phenomena will permit eventual design of a small commercial or pilot plant gasifier on a substantially larger scale.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1981-82	$24,600			$24,600
1982-83	$22,900			$47,500
1983-84	$15,900			$63,400

CONTINUED

REPORTS
STATUS AND COMMENT

PROJECT DATA SHEET # 336		**PROGRAM IDENTIFICATION**	4.3.6.5 Biomass Conversion Technologies/ Methanol
TITLE	Improved Alcohol Synthesis Through Periodic Operation	**DURATION**	November 1982 - November 1985
CONTRACT #	Strategic Grant	**COST**	$57,700
CONTRACTOR	University of Waterloo Dept. of Chemical Engineering Waterloo, Ontario N2L 3G1	**SPONSOR**	Natural Sciences and Engineering Research Council
PRINCIPAL INVESTIGATOR	R. Hudgins		

OBJECTIVE

1. A thorough study of forced feed composition cycling of carbon dioxide dosing on methanol synthesis on one or more Cu-ZnO catalysts. This will be done in order to find an optimal method of dosing and to understand the parameters involved in the process. Patent coverage is likely for some of these results.
2. The completion of the current study of CO oxidation on CuO catalyst using FTIR spectroscopy to detect CO intermediates on the surface of the catalyst.
3. Extension of the work in 2. to methanol synthesis so as to examine surface behaviour in periodic dosing. Through this research we hope to understand why periodic dosing with carbon dioxide is more effective than in its absence.

DESCRIPTION

The main products obtained with Cu-ZnO catalyst were methanol and methane. Reaction appeared to be surface controlled in the range of conditions studied. Forced feed composition cycling suppressed methanol yields but significantly enhanced methane yields. Only with the largest amplitudes and the shortest periods (6 min) was it possible to raise the time-average methanol yields to the steady-state value.

An alternate method of activating a catalyst is to dose it periodically with an agent which causes an activity change. It is well established in industrial practice that the activity of a Cu-ZnO catalyst can be raised several-fold by the addition of a small volume (up to 12%) of CO to the feed (Stiles, 1977). This idea was attempted in the forced feed composition cycling mode by Mr. Luigi Fabbricino. From this study, it was concluded that periodic dosing of the catalyst with CO (2% by volume as averaged in time across a cycle) improved methanol formation by as much as 25% compared with maintaining a steady dosing level of 2% CO in the synthesis mixture. Periodic dosing also reduced methane formation. This result is seen to have important consequences for continued study of this topic, namely, to examine improved policies for CO dosing, as has now been begun by Mr. Kishore Chanchlani in our laboratory. Carbon dioxide dosing has been found to enhance catalytic rates of many forms of the Cu-ZnO-based catalysts for methanol synthesis by several-fold. A complex interplay of amplitude, cycle-split, and period length give rise to the region of enhanced reaction rate and selectivity improvement under forced feed composition cycling operation. Screening tests done in our 1981-83 grant program show improvements of the order of 25% and even higher changes in selectivity. Quite quickly a proper choice of variables could raise this significantly, leading to a "Canadian" methanol process.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1982-83	$21,900			$21,900
1983-84	$17,900			$39,800
1984-85	$17,900			$57,700

REPORTS

CONTINUED

STATUS AND COMMENT

Working in collaboration with P.L. Silveston, Chemical Engineering, University of Waterloo. R.H.
84/12/01

PROJECT DATA SHEET # 153

TITLE Wood Residues as Fuel for Lime Kilns

CONTRACT #
42SS.KL229-0-4121 (0SS80-35)
1-4113
23216-3-6152 (0SS83-00037)
C-123

CONTRACTOR
Pulp and Paper Research Inst.
570 St. John's Blvd.
Pointe Claire, Que. H9R 3J9

PRINCIPAL INVESTIGATOR
M.K. Azarniouch
R.J. Philp

PROGRAM IDENTIFICATION
4.3.6.6
Biomass Conversion Technologies/ Direct Combustion

DURATION April 1980 - March 1984

COST $739,908

SPONSOR Energy, Mines and Resources

SCIENTIFIC AUTHORITY
A. Dolenko
Renewable Energy Division
Energy, Mines and Resources
469 O'Connor Street
Ottawa, Ontario
K1A 5H3

OBJECTIVE

To establish the feasibility of substantial (20-50%) replacement of fossil fuel in a mill lime kiln by feeding hog fuel and wood chips, as is, with the lime mud into the cold end of the kiln.

DESCRIPTION

1. Installation of wood chip/hog fuel feeder system.
2. Wood chips and hog fuel tests.
3. Preparation of final report.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1980-81	$163,977			$163,977
1981-82	$179,439			$343,416
1983-84	$255,292	$141,200		$739,908

REPORTS

Wood Residues as Fuel Source for Lime Kilns by R.J. Philp, M.K. Azarniouch, Pulp and Paper Research Institute of Canada, August 1981. (Available from ENFOR Secretariat or CISTI Energy Library)

Wood Residues as Fuel Source for Lime Kilns by R.J. Philp, M.K. Azarniouch, Pulp and Paper Research Institute of Canada, November 1982. (Available from ENFOR Secretariat or CISTI Energy Library)

PPRIC, 1983, "Wood Residues as Fuel Source for Lime Kilns," ENFOR Project C-123.

STATUS AND COMMENT

PROJECT DATA SHEET # 376

TITLE Wood Firing of Lime Kilns in Bleached Kraft Mills

CONTRACT # 23216-3-6138 (DSS83-00024)
C-401

CONTRACTOR Domtar Inc.
Research Centre
Senneville, Quebec
H9X 3L7

PRINCIPAL INVESTIGATOR A.J. Campbell
Tele.: (514) 457-6810

PROGRAM IDENTIFICATION 4.3.6.6
Biomass Conversion Technologies/
Direct Combustion

DURATION May 1983 - March 1984

COST $139,075

SPONSOR Energy, Mines & Resources

SCIENTIFIC AUTHORITY A.J. Dolenko
Renewable Energy Division
Energy, Mines & Resources
460 O'Connor Street
Ottawa, Ontario
K1A 0E4
Tele.: (613) 995-9447

OBJECTIVE

1. To determine the effects of direct firing, air suspension burning of wood in a bleached kraft mill lime kiln on lime, liquor and pulp quality.
2. To estimate the economic viability of a commercial installation.

DESCRIPTION

Phase I: Visit a pulp mill in Pitea, Sweden, to collect various samples, examine the samples and compare the results to those obtained by examination of similar samples from a typical Canadian pulp mill and from a specified Swedish pulp mill.
Phase II: Conduct pilot plant pulping and bleaching experiments using typical Canadian wood and white liquor from the Pitea mill or synthetic liquor containing the same inpurities as the Pitea mill and evaluate the quality of the pulp produced; and,
Phase III: Carry out an economic analysis to establish the viability, in Canada, of using wood to fire a lime kiln.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$139,075			$139,075

REPORTS

Campbell, A.J., Lightfoot, H.D., Lowe, R.W., O'Malley, B.F., "Wood Waste Firing of Bleached Kraft Mill Lime Kilns." Senneville, Quebec, ENFOR Project C-401, March 1984.

STATUS AND COMMENT

Project C-401 completed

PROJECT DATA SHEET # 377

TITLE Tall oil as a Fuel for Mobile Equipment in the Kraft Pulp Industry

CONTRACT # 23216-3-6140 (05583-00017)
C-390

CONTRACTOR Prince Albert Pulp Company Ltd.
Box 3001
Prince Albert, Saskatchewan
S6V 5T5

PRINCIPAL INVESTIGATOR A. Twa
Tele.: (306) 764-1521

PROGRAM IDENTIFICATION 4.3.6.6
Biomass Conversion Technologies/
Direct Combustion

DURATION May 1983 - July 1984

COST $198,130

SPONSOR Energy, Mines and Resources

SCIENTIFIC AUTHORITY A.J. Dolenko
Renewable Energy Division
Energy, Mines and Resources
460 O'Connor Street
Ottawa, Ontario
K1A 0E4
Tele.: (613) 995-9447

OBJECTIVE

To evaluate the potential of using crude, or upgraded tall oil as fuel in mobile equipment for woodland operation.

DESCRIPTION

1. Crude Tall oil representing regional and seasonal variations will be tested for fuel characteristics.
2. Crude Tall oils will be tested in a laboratory diesel engine.
3. Upgraded tall oils and components such as fatty acids and its methyl esters will be tested in a laboratory diesel engine.
4. An economic analysis will be made to assess the feasibility of burning tall oil and upgraded products in diesel engines.
5. A final report will be made with recommendations.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$198,130			$198,130

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET #	378
TITLE	Suspension Firing of Pulverized Biomass in Large Industrial Boilers
CONTRACT #	23216-3-6148 (OSS83-00040) C-343
CONTRACTOR	Millar Enterprises 3756 Joyce Avenue Powell River, British Columbia V8A 2Y8
PRINCIPAL INVESTIGATOR	A. Millar Tele.: (604) 485-9425
PROGRAM IDENTIFICATION	4.3.6.6 Biomass Conversion Technologies/ Direct Combustion
DURATION	June 1983 - March 1984
COST	$54,200
SPONSOR	Energy, Mines & Resources
SCIENTIFIC AUTHORITY	A.J. Dolenko Renewable Energy Division Energy, Mines & Resources 460 O'Connor Street Ottawa, Ontario K1A OE4 Tele.: (613) 995-9447

OBJECTIVE

To report state-of-the-art of suspension burning both as original design and retrofit.

DESCRIPTION

Data will be obtained on the following installations: Potlatch Corp., Lewiston, Idaho; ASSI, Lovholmen, Pitea, Sweden; Great Lake Paper, Thunder Bay, Ontario; Buckeye Cellulose, Perry, Fla.; Proctor & Gamble, Grand Prairie, Alberta; Arkansas Kraft, Morrilton, Arkansas.
The initial data will be obtained by correspondence with the operating companies, suppliers and consultants. After preliminary screening and cataloguing field trips will be made to a maximum of four mills to view operation, confirm operating data and interview operators.
After completion of field trips a preliminary report will be issued to the T.L.O. Following this review any required changes will be made and a final report will be issued.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$54,200			$54,200

REPORTS

AMOS D.L., BRISCOE B.G., and MILLAR A.S., "Susoension firing of Pulverized Biomass in Large Industrial Boilers," ENFOR C-343, February 1984.

STATUS AND COMMENT

Project C-343 completed.

84/12/06

PROJECT DATA SHEET # 414

TITLE Fluidized Bed Recovery of Kraft Black Liquor

CONTRACT # Strategic Grant

CONTRACTOR McGill University
Chemical Engineering Dept.
Montreal, Quebec
H3A 2A7

PRINCIPAL INVESTIGATOR M.M. Avedesian
A.S. Mujumdar

PROGRAM IDENTIFICATION 4.3.6.6
Biomass Conversion Technologies/
Direct Combustion

DURATION November 1983 - November 1987

COST $123,000

SPONSOR Natural Sciences and
Engineering Research
Council of Canada

OBJECTIVE

- To develop a fundamental understanding of the complex chemical and physical processes occuring during the combustion of Kraft black liquor and the recovery of inorganic chemicals in a fluidized bed for Kraft mill recovery. To date, no such understanding exists for this industrially important process for pulp and paper manufacturing.
- Based on the fundamental understanding developed in No. 1, to develop a model which adequately describes the chemical and physical processes for black liquor recovery in a fluidized bed. This model will be used to predict the effect of changes in black liquor properties and process variables on the operability and product quality of inorganic pellets. To date, there does not exist a reliable model that could be used by industry for the purpose of prediction and control.
- To determine under what conditions the black liquor from Kraft mill can be gasified in a fluidized bed to produce a low BTU gas and inorganic pellets containing NaCO and NaS. This is a novel idea that has never been tried. If successful this would significantly reduce the capital and operating costs for black liquor recovery. The capital cost would be reduced because the requirement for a separate reduction vessel to reduce NaSO4 to NaS would be eliminated. The operating cost would be reduced because the overall energy efficiency would be increased by increasing the steam production and rolling back the equipment for fossil fuel in the supplemental steam generators.

The above three objectives reflect the logic of this project. It is planned to develop a better fundamental understanding of the existing fluid bed Kraft recovery process which is operated in an oxidizing mode (combustion + recovery). This will then be extended to a new regime of operation; the reducing mode (gasification + recovery).

CONTINUED

DESCRIPTION

It is recognized that the Kraft process for pulp production will be used by the industry for many years to come. The pulping chemicals NaOH and NaS extract lignin from the wood to produce a pulp and a weak black liquor. The weak black liquor contains water, organic lignin derivatives and inorganic compounds derived from the Na. An essential criterion for the economic viability of the Kraft process is the recovery of inorganic chemicals for recycle to pulping and the production of process steam.

The original Tomlinson recovery furnace was developed in the 1930's. Since that time, several modifications and design improvements have been carried out, however the original concept is still retained and universally practiced throughout the industry. Weak black liquor is concentrated to about 65% total solids in multiple effect evaporators and burnt in the recovery furnace at about 980C. The organic constituents in the black liquor provide the fuel for combustion. The inorganic NaCO and NaSO4 form a smelt (at these high temperatures) at the bottom of the furnace and pass through a char bed where the NaSO4 is reduced to NaS.

Subsequently, the NaCO is causticized with CaO to regenerated the NaOH required for pulping.

The recovery furnace contains boiler tubes in which steam is raised for process purposes.

The two major shortcomings of this conventional process are the smelt/water explosions and the high capital and operating costs. Periodically, the steam tubes inside the furnace burst causing water to flow on the smelt and explode. These explosions are dangerous and have sometimes caused death. They are extremely costly and the insurance premiums are high. The maintenance costs are also high because of the above.

The fluidized bed process is a recent development and not yet widely practiced in the industry. In this process, weak black liquor is concentrated to only about 42% total solids. It is sprayed above the fluidized bed of inorganic pellets containing about 70% NaSO4 and 0% NaCO. The black liquor probably evaporates, pyrolyzes followed by combustion of the organic constituents to provide the thermal energy. The resulting inorganic NaSO4 and NaCO form pellets so that new pellets are created. Possibly, some of the liquor coats the existing pellets so that they also grow with time. The fluidized bed operates at a much lower temperature (700C) so that no smelt is formed and the inorganics remain in the solid phase. Thus, there is no danger of explosion and the capital cost is much less because expensive water wall construciton is not required and the fluid bed vessel is much simpler in design and construciton. The black liquor feed contains only 42% total solids (compared with 65% for the conventional process) so that the mean bed temperature can be kept at 700C i.e. much below the fusion temperature of the pellets. There is no in-bed heat exchanger and the overall energy efficiency is much less than that of the conventional process. The inorganic pellets are subsequently fed onto the char bed of the conventional recovery furnace to reduce the NaSO4 to NaS.

The major advantages of the fluid bed process over the conventional Tomlinson recovery furnace are that it eliminates the dangerous smelt/water explosion and the capital cost is much less. However, the major shortcomings of the fluid bed process are that periodically there are local temperature excursions above the fusion temperature and the pellets sinter and agglomerate causing large build-ups resulting in shut-downs; temperature control is difficult and influenced by the solids content of the feed liquor and the spray characteristics; the overall energy efficiency is much less because the solids content of the feed is lower, i.e. the steam economy in the fluid bed is 1 whereas in the multiple effect evaporator it is 4.5; the pellets must be reduced in a separate vessel.

The first fluid bed Kraft recovery process was installed at the Cornwall mill of Domtar Fine Papers Ltd. in March 1975. Many problems prevented its continuous operation. A task force was established in April 1977 and over a period of two years, the availability was increased from30% to 90%. The major operating problems were: control of pellet size, build-up and agglomeration in the bed and in the expanded freeboard region and partial burning of the liquor above the bed causing excessive freeboard temperatures resulting in very sticky dust. Since 1979, the operating personnel at Cornwall have learned to control and operate the process with the associated problems.

It is the purpose of the present research project to develop a better fundamental understanding of the complex processes being carried out in the fluidized bed in order to resolved the operating problems and sensitivities and to better control the process. Also, if the fluid bed can be operated in the gasification mode rather than the combustion mode, the overall energy efficiency will be increased and the need for separate reduction will be eliminated.

The commercial use of fluid beds for Kraft recovery is a very recent development and the only commercial unit operating in the world today is at the Cornwall Plant. It is about 9 m in diameter at the lower hearth with an expanded freeboard. There are only four papers which describe the commercial operational at Cornwall with its attendant problems.

CONTINUED

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1983-84 1984-85 1985-86	$31,000 $45,500 $46,500			$ 31,000 $ 76,500 $123,000

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 479		**PROGRAM IDENTIFICATION**	4.3.6.6 Biomass Conversion Technologies/ Direct Combustion
TITLE	Concentric Vortex Chaff Furnace for Grain Drying & Space Heating	**DURATION**	March 1984 - December 1985
CONTRACT #	01916-3-ER37(0SG83-00226)	**COST**	$166,887
CONTRACTOR	Canadian Resourcecon (1983) Ltd. Vancouver, British Columbia	**SPONSOR**	Agriculture Canada
PRINCIPAL INVESTIGATOR	G.A. Constable	**SCIENTIFIC AUTHORITY**	D. Campbell Agriculture Canada Box 1030 Swift Current, Saskatchewan S9H 3X2 Tele.: (306) 773-4621

OBJECTIVE

To develop, test and evaluate a scaled-down version of an already existing furnace for the suspension burning of chaff or the pile burning of solid fuels such as sunflower stalks, corn stover and cobs, poultry litter and wood chips. Test two applications: space heating and crop drying. Compare to fossil fuel system. Assess on-farm practicability, availability and economics.

DESCRIPTION

Phase I. Assess chaff supply: quantity available, characteristics and soil value.
Design the furnace.
Select farms for on-farm evaluation.
Sizing of furnace: drier retrofit and space heat retrofit.
Phase II. System development: modification, fabrication and shop testing of furnace.
System Evaluation: installation, operation and monitoring.
Comparative economic analysis.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1984-85	$ 39,915			$ 39,915
1985-86	$126,972			$166,887

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 481

TITLE Determine the Feasibility of Using Residues from Apples for Combustion

CONTRACT # 01916-3-ER36

CONTRACTOR
Richard Russo Bernier
et Associés Incorporé
2020 University, Bureau 1520
Montréal, Québec
H3A 2A5

PRINCIPAL INVESTIGATOR R. Bernier

PROGRAM IDENTIFICATION 4.3.6.6
Biomass Conversion Technologies/
Direct Combustion

DURATION March 1983 - November 1984

COST $66,669

SPONSOR Agriculture Canada

SCIENTIFIC AUTHORITY
R. Chagnon
Centre de recherches
de St-Jean
Agriculture Canada
Case postale 457
430 boul. Gouin
St-Jean, Québec
J3B 6Z8

OBJECTIVE

To study the feasibility of using residues, obtained from the production of apple juice, as a fuel to produce steam which can be used to sterilise the juice.

DESCRIPTION

1. Establish the produciton cycle of the residues during apple juice production.
2. Obtain samples of the residues and carry out analyses in order to characterize them.
3. Dry at various humidity levels, 40 tonnes of these residues.
4. Carry out combustion trials in an experimental boiler of the various dried fractions.
5. Determine the levels of energy production and the efficiency of combustion.
6. Carry out energy balances on the process and evaluate viability.
7. Make recommendations with respect to the apple juice production facility.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1983-84	$60,000			$60,000
1984-85	$ 6,669			$66,669

REPORTS

The final report is available through CISTI

STATUS AND COMMENT

The project is complete. For the production facility studied, it is economical to dry and burn the apple residues for steam production. The boilers are currently burning oil.

84/10/30

PROJECT DATA SHEET # 186A

TITLE Coordination of the test program on boilers burning wood refuse

CONTRACT # KL229-1-4124-B C-235
KL229-1-4124-3

CONTRACTOR Canadian Boiler Society
1 Yonge St., Suite 1400
Toronto, Ontario.
M5E 1J9

PRINCIPAL INVESTIGATOR W. Newby

PROGRAM IDENTIFICATION 4.3.6.6
Biomass Conversion Technologies/
Direct Combustion

DURATION August 1981 - March 1984

COST $207,000

SPONSOR Environment Canada

SCIENTIFIC AUTHORITY G.K. Lee
Canadian Combustion Research Laboratory
Energy Research Laboratories
Bells Corners Complex
c/o 555 Booth Street
Ottawa, Ontario. K1A 0G1
(613) 996-4570 ext. 186

OBJECTIVE

To identify boiler installations which reflect post 1976 combustion and control technology, and to perform detailed efficiency and emissions tests on selected units.

DESCRIPTION

Task 1 The contractor shall perform whatever work may be required to assist in the planning of the total program.

Task 2 (A) Together with federal government representatives, Foster-Wheeler Ltd., Babcock and Wilcox Canada Limited, and Combustion Engineering Super Heater Limited, the contractor shall make a visit to Newcastle, N.B., to assess the capability of steam generators operated by Boise Cascade to fire wood refuse. The boilers should preferably be rated at 45,360 kg/h of steam or more.

(B) To determine
(i) current technology features
(ii) which units are most appropriate for measuring ASME indirect boiler efficiencies and EPA emissions characteristics

(C) To identify one boiler for detailed field evaluations.

Task 3 Detailed test plans specifying firing conditions, loads and fuels, emissions measurements, sampling points, and combustion data.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1981-82	$33,000			$ 33,000
1982-83	$97,000			$130,000
1983-84	$77,000			$207,000

REPORTS

Interim reports will be made available only at conclusion of all testing.

STATUS AND COMMENT

Work on-going into 1983. Field tests have been completed in Newcastle, N.B., Harmac, B.C., and Port Alfred. See data sheet #186B for description of testing work by Envirocon Eastern Limited.
84/12/03

PROJECT DATA SHEET # 1868

TITLE Test Program on Boilers Burning Wood Refuse

CONTRACT # KL229-1-4124-1 (DSS82-0002)
C-235, C-358

CONTRACTOR Envirocon Eastern Ltd.
1705 Argentia Road
Mississauga, Ontario
L5N, 3A9

PRINCIPAL INVESTIGATOR J. Trought
(416) 821-4260

PROGRAM IDENTIFICATION 4.3.6.6
Biomass Conversion Technologies/
Direct Combustion

DURATION February 1982 - May 1984

COST $520,128

SPONSOR Energy, Mines and Resources

SCIENTIFIC AUTHORITY G.K. Lee
CANMET
Energy, Mines and Resources
555 Booth Street
Ottawa, Ontario
K1A 0G1
(613) 996-4570 ext. 186

OBJECTIVE

To improve combustion efficiency and operation of large-scale hogged fuel boilers.
To study emissions from large scale hogged fuel boilers
To further the development of the technology of industrial hogged fuel boilers and improve the techniques of testing industrial hogged fuel boilers.

DESCRIPTION

At the Boise-Cascade mill of New Castle (N.B.) and at the Harmac mill of MacMillan Bloedel (B.C.) efficiencies would be determined by ASME Heat Loss method. Pollutants discharged would be determined by sampling the gas stream at strategic locations.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR	NRC	CUMULATIVE TOTAL
1982-83	$463,451			$463,451
1983-84	$ 19,864			$483,315
1984-85	$ 36,813			$520,128

REPORTS

Eleven reports in preparation consisting of five volumes describing the test work at the three sites.

STATUS AND COMMENT

Draft reports scheduled for completion November 1984
Final reports will be released after all final drafts are approved and printed.
84/12/03

PROJECT DATA SHEET # 84

TITLE Wood Liquefaction through the Operation of a Continuous/Semi-Continuous Wood Liquefaction Unit

CONTRACT # KL229-9-7053 (OSS79-00017) C44
23216-3-6143 (OSU83-00011)

CONTRACTOR University of Toronto
Simcoe Hall, Room 1335
Toronto, Ontario
M5S 1A1

PRINCIPAL INVESTIGATOR D.G.B. Boocock
Tele.: (416) 978-4019

PROGRAM IDENTIFICATION 4.3.6.8
Biomass Conversion Technologies/Oil Production

DURATION April 1979 - March 1984

COST $212,498

SPONSOR Energy, Mines & Resources

SCIENTIFIC AUTHORITY R.P. Overend
National Research Council
Division of Energy
Building R-105, Rm 135
Ottawa, Ontario
K1A OR6
Tele.: (613) 993-1342

OBJECTIVE

1. To operate a laboratory scale continuous/semi-continuous unit constructed under ENFOR contract C-44 and thereby gather performance data.
2. To compare these results with those obtained from a fast heat-up batch liquefaction unit and hence determine the better process of the two.
3. To investigate the upgrading of oils produced in wood liquefaction through the operation of a bench scale cracking unit.

DESCRIPTION

An existing laboratory scale wood liquefaction unit will be operated to obtain operating data related to feed rate, product discharge rate, slurry density and catalyst loading. A rapid heat-up batch system will also be operated. Comparison of data will take place to determine the most suitable process. Studies will also take place on the upgrading of the oil products using a laboratory scale cracking unit.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1979-80	$44,328			$ 44,328
1980-81	$36,880			$ 81,208
1981-82	$28,792			$110,000
1982-83	$38,383			$148,383
1983-84	$64,115			$212,498

REPORTS

AGBLEVOR F., CHOW D., CHOWDHURY A., HOLYSH M., PORRETTA F. and BOOCOCK D.G.B., "Update on Wood Liquefaction Studies at the University of Toronto", In Proc. of "Comptes Rendus de l'Atelier de Travail sur la Liqufaction de la Biomasse", 10-33, Sherbrooke, Québec, Sept 29-30, 1983, NRCC 23130.

BOOCOCK D.G.B. and MACKAY D., "Further Development of Processes for the Conversion of Wood to Liquid Fuels through Operation of a Continuous/Semi-Continuous Liquefaction Unit", Final Report, April 1983.

BOOCOCK D.G.B and MACKAY D, "Development of a Process for Conversion of Wood into Liquid Fuel", Final Report, July 1982.

Biomass Liquefaction in Canada: A Review of the Current Status. Proceedings of a workshop held at University of Toronto, August 12, 1980. Compiled and edited by D.G.B. Boocock, D. Mackay and S. Paterson, Department of Chem. Eng. and Applied Chemistry, University of Toronto.

CONTINUED

STATUS AND COMMENT

Final report has been received 84/12/01

PROJECT DATA SHEET # 97

TITLE Liquid Fuels & Chemicals from Aspen.

CONTRACT # 055S.KL229-9-7112
(05579-00057) C-48

CONTRACTOR University of Saskatchewan
Dept. Chemistry & Chemical Engineering
Saskatoon, Saskatchewan

PRINCIPAL INVESTIGATOR R.L. Eager 343-2954
J.F. Matthews 343-3080
J.M. Pepper 343-2950
area code (306)

PROGRAM IDENTIFICATION 4.3.6.8
Biomass Conversion Technologies/
Oil Production

DURATION April 1979 - July 1984

COST $338,826

SPONSOR Energy, Mines & Resources

SCIENTIFIC AUTHORITY A.J. Dolenko
Conservation & Renewable
Energy Mines and Resources
460 O'Connor Street
Ottawa, Ontario
K1A 0E4
Tele.: (613) 995-9447

OBJECTIVE

To conduct a detailed study of the conversion of aspen wood into a portable sulfur-free fuel oil as the major fraction and a variety of oxygenated chemicals (alcohols, ketones and acids) with solvent properties. The process involves the interaction of wood with carbon monoxide in the presence of a catalyst.

DESCRIPTION

The research includes an examination, using a small-scale batch apparatus, of the major process variables: temperature, reaction time, relation of carbon monoxide to substrate, nature and amount of catalyst in an attempt to optimize the production of oil and chemicals.
First Year - Completion of initial study of process variables using batch reactor; Initial studies on use of recycled oil as reaction medium; Completion of separation and identification of major low-boiling components of water-soluble fraction.
Second Year - Completion of studies on use of recycled oil as reaction medium; Continuation of isolation and identification of higher-boiling water-soluble fractions; Design, construction and initial use of small-scale continuous flow reactor; Development of proposed mechanism of reaction and role of each of the cellulose, hemicellulose and lignin fractions of the wood.
Third Year - Operation of a small-scale, semi-continuous operation equipment to determine more reliable data on the kinetics of the process to be used to obtain an economic evaluation of an industrial-sized operation. (This phase has been extended into the fourth year.)

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1979-80	$ 32,407			$ 32,407
1980-81	$ 45,974			$ 78,381
1981-82	$ 68,392			$146,773
1982-83	$ 91,306			$238,079
1983-84	$100,747			$338,826

REPORTS

PEPPER J.M., EAGER R.L. and MATTHEWS J.F., "Study of the Conversion of Lignocellulosic (Aspen) Materials to Liquid Fuels and Chemicals," University of Saskatchewan, Saskatoon, Sask. March 1981. ENFOR Project C-48(1). (Available from ENFOR Secretariat.)

PEPPER J.M., EAGER R.L. and MATTHEWS J.F., "Production of Liquid Fuels and Chemicals from Lignocellulosic (Aspen) Materials," University of Saskatchewan, Saskatoon, Sask. 1982. ENFOR Project C-48(2). Final Report.

PEPPER J.M., EAGER R.L., and MATTHEWS J.F., "Production of Liquid Fuels and Chemicals from Lignocellulosic (Aspen) Material," Univesity of Saskatchewan, Saskatoon, 1983, ENFOR Project C-48(3)

CONTINUED

STATUS AND COMMENT

PROJECT DATA SHEET #	198	**PROGRAM IDENTIFICATION**	4.3.6.8 Biomass Conversion Technology/ Oil Production-Liquefaction
TITLE	Hydrogenation using Short Retention Times	**DURATION**	November 1980 - November 1983
CONTRACT #	Strategic Grant	**COST**	$169,227
CONTRACTOR	University of Sherbrooke Chemical Engineering Sherbrooke Quebec J1K 2R1	**SPONSOR**	Natural Science and Engineering Research Council of Canada
PRINCIPAL INVESTIGATOR	E. Chornet Tel.: (819) 565-4320		

OBJECTIVE

To develop the pyrolytic technique of hydrogenolysis/hydrogenation using short retnetion times for the production of pyroligneous oils.

DESCRIPTION

The work is to include:

1. The development of comparative studies on the influence of long and short contact times in the hydrogenolysis reaction.
2. The development of basic experimental data on the step approach to hydrogenolysis: a) selective hydrolysis followed by hydrogenation; b) pyrolysis under vacuum and hydrogenation of the iquids and solids produced.
3. A characterization of the products.
4. A microscopic examination of the complex particles during the process.
5. The role of CO and its interaction with the solvent.
6. Modifications to the catalysts.
7. The design and construction of a new reactor using the high shear, high mixing speed nozzle concept for treating biomass materials and upgrading primary products.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1980-81	$49,260			$ 49,260
1981-82	$60,363			$109,623
1982-83	$59,604			$169,227

REPORTS

Related publications as of 1980.

CHORNET E., FONSECA R., GRANDBOIS M., and BROWN R.P., "The Conversion of Peat and Humic Materials into Liquid Fuels Using Carbon Monoxide," Can. J. Chem. Eng., accepted for publication, April 1980.

KIENNEMANN A. and CHORNET E., "A Study of the Methanation Reaction Using Simple Metal-Doped Peat-Derived Carbons," I & EC Products Res. Dev., accepted for publication, April 1980.

ROY C., BELLEMARE G.R. and CHORNET E., "The Effect of Sensitivity Setting of a Katharometer on Response Factors at Low Concentrations," J. of Chromatography, accepted for publication, April 1980.

RAMUSAT J.F. and CHORNET E., "Décoloration et détoxification de Salle d'Écorçage à l'aide d'un charbon provenant de la pyrolyse des écorces," Water Poll, Res. Can., accepted for publication, April 1980.

STATUS AND COMMENT

PROJECT DATA SHEET # 235

TITLE Production of Oils from Wood

CONTRACT # Strategic Grant

CONTRACTOR Université Laval
Génie Chimique
Québec, Québec

PRINCIPAL INVESTIGATOR S.C. Kaliaguine

PROGRAM IDENTIFICATION 4.3.6.8
Biomass Conversion Technologies/
Oil Production-Liquefaction

DURATION November 1981 - November 1984

COST $206,884

SPONSOR Natural Sciences and
Engineering Research Council

OBJECTIVE

This project includes a study of the technique for the production and the upgrading of pyrolytic oils prepared from wood. For the production we propose to employ the technique of supercritical extraction considered to be particularly promising economically, since it avoids the costs of the production and compression of the reducing gases. For the upgrading, we propose to use the catalyst ZSM-5 which enables the production of gasoline from methanol and a number of other organic compounds containing oxygen.

DESCRIPTION

Sub-Project 1: Production of pyrolytic oils by the super-critical extraction method. The aim is to study the conditions of mass transfer and also heat transfer during pyrolysis. We are interested not only on the effect of these parameters on the conversion into liquid product, but also on their effect on the conversion into gasoline obtained in the course of the standard ZSM-5 process.
Sub-Project 2: The study of the conversion of the pyrolytic oils on ZSM-5. The object will be to determine the optimum conditions of the catalytic procedure for the production of gasoline in the absence of all additional reactants by using a pulse reactor. By using the oils produced in sub-project 1 as reactants in sub-project 2, allows the simultaneous optimization of the two procedures, the production of the oils and their upgrading.
Sub-Project 3: The study of the conditions for the synthesis of zeolite ZSM-5 and the catalysts obtained by depositing different metals in the zeolite. The properties of the catalysts thus obtained, will also be studied by examining the reaction of the major constituents such as phenol, pyrogallol, and levoglucosan with CO and the mixture of CO and H under pressure. The object is to investigate the catalysts which can be used to produce the reaction in sub-project 2(mainly a dehydration) and at the same time with the reaction of gas to water in order to eliminate oxygen which enters the oil in the form of CO.

FUNDING

FISCAL YEAR	SPONSOR	EQUIPMENT		CUMULATIVE TOTAL
1981-82	$48,500	$32,779		$ 81,279
1982-83	$52,127	$30,978		$164,384
1983-84	$42,500			$206,884

REPORTS

Related publications as of June 1984

LABRECQUE R., KALIAGUINE S., and GRANDMAISON J.L., "Supercritical Gas Extraction of Wood With Methanol," I.E.C. Proc. Res. Dev., 23, 177 (1984)

CHANTAL P., KALIAGUINE S., GRANDMAISON J.L. and MAHAY A., "Production of Hydrocarbons from Aspen Poplar Pyrolytic Oils Over H-ZSM5," Applied Catalysis, 10, 317 (1984).

SZOGHY I., MAHAY A., and KALIAGUINE S., "Elemental Analysis of Zeolites by PIXGE," To be published in Zeolites.

CONTINUED

STATUS AND COMMENT

The three sub-projects are proceeding satisfactorily. On project 1, a master thesis was defended, a second work was completed and the third will end up with the defense of another master thesis in December 84. Each of sub-projects 2 and 3 will yield a doctoral thesis in the Spring of 1985. several publications are in preparation. Since 1982, nine (9) presentations in national and international meetings have been made.

84/12/04

PROJECT DATA SHEET #	339	**PROGRAM IDENTIFICATION**	4.3.6.8 Biomass Conversion Technologies/ Oil Production-Liquefaction
TITLE	Chemical Characterization of Wood Conversion to Liquid Fuels	**DURATION**	November 1982 - November 1985
CONTRACT #	Strategic Grant	**COST**	$84,000
CONTRACTOR	University of Toronto Dept. of Chemical Eng. Toronto, Ontario M5S 1A1	**SPONSOR**	Natural Sciences and Engineering Research Council
PRINCIPAL INVESTIGATOR	T.T. Tidwell		

OBJECTIVE

To analyse oil samples produced via liquefaction of biomass, to gain an understanding of the chemical processes involved in liquefaction and to use this understanding to optimize the liquefaction process for the production of useful materials.

DESCRIPTION

The work involves analysis of the chemical composition of wood oils produced from several liquefaction processes using different wood clones and parts of trees (bark, sapwood) as well as model compounds (cellulose, cellobiose, glucose, fructose, etc). Knowledge of the chemical composition of the oils produced and the variation in the composition as a function of reaction conditions allows the process to be optimized for desired product compositions. Mechanistic hypotheses for the chemical transformations are devised and tested using appropriate model compounds. The distinctive product compositions from different wood clones, tree parts, and model compounds are characteristic of the source, and will be used in the interpretation of the original structures and their chemical transformation.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1982-83	$28,000			$28,000
1983-84	$28,000			$56,000
1984-85	$28,000			$84,000

REPORTS

STATUS AND COMMENT

Working in collaboration with D.G.B. Boocock, Dept. of Chemical Engineering.

84/12/06

PROJECT DATA SHEET # 362

TITLE
Program for Pilot Studies on the Liquefaction of Poplar

CONTRACT #
23216-3-6243 (OSU83-00084)

CONTRACTOR
University of Sherbrooke
Sherbooke, Quebec
J1K 2R1

PRINCIPAL INVESTIGATOR
E. Chornet

PROGRAM IDENTIFICATION
4.3.6.8
Biomass Conversion Technologies/
Oil production-Liquefaction

DURATION
July 1983 - March 1984

COST
$28,750

SPONSOR
Bioenergy Program
National Research Council

SCIENTIFIC AUTHORITY
R.P. Overend
National Research Council
Division of Energy
Building R-105, Rm 135
Ottawa, Ontario
K1A OR6
Tele.: (613) 993-1342

OBJECTIVE

The liquefaction of standard wood samples provided by the IEA.

DESCRIPTION

A standard IEA wood sample provided to the University of Sherbrooke is to be processed in the liquefaction apparatus according to standard operating procedures. The university is to report on mass & energy balances and provide a sample of their oil for analysis by Battelle Laboratories.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$28,750			$28,750

REPORTS

Results will be reported in the final report of the IEA BLTF study. (see data sheet #191) as well as being available in NRCC 23130 "Comptes rendus de l'atelier de travail sur la liquefaction de la biomasse"

STATUS AND COMMENT

Completed

R.P.O. 84/11/29

PROJECT DATA SHEET # 366

TITLE Liquefaction of Poplar Wood & Peat by Supercritical Fluid Extraction

CONTRACT # 31926-3-0043 (0SB83-00097)

CONTRACTOR
B.C. Research
3650 Wesbrook Mall
Vancouver, B.C.
V6S 2L2

PRINCIPAL INVESTIGATOR
J. Howard
E.C. McDonald

PROGRAM IDENTIFICATION
4.3.6.8
Biomass Conversion Technologies/
Oil Production-Liquefaction

DURATION April 1983 - October 1983

COST $37,500

SPONSOR
Bioenergy Program
National Research Council

SCIENTIFIC AUTHORITY
R.P. Overend
National Research Council
Division of Energy
Building R-105, Rm 135
Ottawa, Ontario
K1A OR6
Tele.: (613) 993-1342

OBJECTIVE

To participate in the International Energy Agency's evaluation of biomass liquefaction processes using standardized feedstocks of poplar wood and peat.
To prepare poplar wood and peat oils by supercritical fluid extraction and compare their composition to those of oils produced by other liquefaction processes.
To obtain data on heat and energy requirements for the supercritical fluid extraction process

DESCRIPTION

The first stage is the modification of existing equipment to allow measurement of solvent losses and heating rates in the process. A brief review of our supercritical fluid extraction process carried out by Mr. D. Beckman for the International Energy Agency showed that the solvent loss and the heating rate were the main areas where more information was required. The estimated cost of producing wood oils by supercritical fluid extraction is very dependent on solvent losses. In the 1982 Final Report for Project No. C-51, "Chemicals from Forest Products by Supercritical Gas Extraction", the cost of a barrel of oil was estimated to be $42 with a solvent loss of 2% based on dry feed, and $56 with a loss of 5%. Previously, the extraction vessel was lowered into the sand bath, and solvent was lost while the connection was made to the catch pot. Raising the sand bath to heat a fixed extraction vessel would eliminate this problem. This modification can be made using readily available materials and without major equipment purchases. The addition of a thermocouple to the extraction vessel would permit measurement of the time required to heat the wood to the extraction temperature. The proposed extraction conditions are: 1) poplar wood/peat extracted with supercritical acetone at 360C and 28 MPa, 2) poplar wood/peat extracted with supercritical acetone at 360C and 10 MPa, 3) poplar wood pretreated with acid then extracted with supercritical acetone at 260C and 10 MPa.
Replicate extractions will be carried out to obtain sufficient oil for analysis. The first set of conditions outlined above will be used to produce a minimum of 100 g of oil for analysis by Pacific Northwest Laboratories using standard analytical procedures.
An evaluation of different processes for the liquefaction of poplar wood, using a standard feedstock sample, will produce a meaningful comparison of the cost of producing the wood oils. The most promising processes will be further evaluated in a proposed Biomass Liquefaction Test Facility, which will provide information necessary to the construction of a full scale plant.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$37,500			$37,500

CONTINUED

REPORTS

Results will be reported in the final report of the IEA BLTF study. (see data sheet # 191) as well as being available in NRCC 23130 "Comptes rendus de l'atelier de travail sur la liquefaction de la biomasse".

STATUS AND COMMENT

Completed

PROJECT DATA SHEET #	371	**PROGRAM IDENTIFICATION**	4.3.6.8 Biomass conversion Technologies/ Oil production - Liquefaction
TITLE	Low Pressure-low Temperature Process for the Conversion of Wood to Liquid Fuels and Chemicals	**DURATION**	April 1983 - May 1984
CONTRACT #	23216-3-6141 (OSU83-00014) C-442	**COST**	$162,000
		SPONSOR	Energy, Mines & Resources
CONTRACTOR	McGill University Office of Industrial Research 853 Sherbrooke Street West Montreal, Québec H3A 2T6	**SCIENTIFIC AUTHORITY**	A.J. Dolenko Conservation and Renewable Energy, Mines & Resources 460 O'Connor Street Ottawa, Ontario K1A OE4 Tele.: (613) 995-9447
PRINCIPAL INVESTIGATOR	W.J.M. Douglas Tele: (514) 392-4963		

OBJECTIVE

To demonstrate experimentally at the bench scale the technical viability of the proposed low pressure-low temperature process for liquefying wood.

DESCRIPTION

To carry out an experimental program to establish the effects of major process variables on conversion yield, reaction rate, etc.
To develop a consistent procedure for material balances, product analysis and characterization.
To Perform experimental runs at optimal conditions.
To Explore various alternatives for recovering iodine.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1983-84 1984-85	$128,705 $ 33,295			$128,705 $162,000

REPORTS

AFRASHTEHFAR S., ALI O., COOKE N., COOPER D., DOUGLAS M. and NG D., "A Low Pressure-Low Temperature Process for the Conversion of Wood to Fuels and Chemicals," in Comptes Rendus de L'Atelier de Travail sur la Liqufaction de la Biomasse, Sept 29-30, 1983, Sherbrooke, Québec, NRCC 23130.

STATUS AND COMMENT

PROJECT DATA SHEET # 393		**PROGRAM IDENTIFICATION**	4.3.6.8 Biomass Conversion Technologies/ Oil Production-Liquefaction
TITLE	The Upgrading and Utilisation of Synthetic Crude Oil Produced by Wood Liquefaction	**DURATION**	September 1983 - September 1984
CONTRACT #	Research Agreements Program	**COST**	$12,240
CONTRACTOR	University of Toronto Chemical Engineering Dept. Toronto, Ontario M5S 1A4	**SPONSOR**	Energy, Mines and Resources Canada
PRINCIPAL INVESTIGATOR	C.G.B Boocock		

OBJECTIVE

(a) Through operation of an existing 1-L autoclave, establish conditions that will deoxygenate phenols without reduction of the aromatic ring.
(b) Through operation of an existing laboratory-scale cracking unit determine the effect of cracking processes on oils produced by wood liquefaction. In particular, measure the degree of coking caused by wood oils.

DESCRIPTION

Since phenolic compounds and other oxygenated compounds make up a considerable fraction of the products, there are two possible scenarios for oil upgrading. Either the phenols are retained (for possible chemical use) or they may be converted to aromatics by deoxygenation. Since the latter would certainly involve the use of hydrogen (which is expensive), reduction of the aromatic rings must be avoided. Thus it is planned to study the deoxygenation of simple phenols using a variety of catalysts. A 1-L autoclave in the group will be dedicated to this study. A catalyst basket has been mounted inside the unit for the purpose of such a study.

Model alkylated phenols will be heated to various temperatures in the presence of different hydrogen pressures and catalysts, and the product mixture will be examined for deoxygenated material, ring reduced product and starting substrate. For example, P-methylphenol (p-tuluol) could yield toluene, methylcyclohexane and methylcyclohexanol. Phenol itself could yield benzene, cyclohexane and cyclohexanol. Such studies have been conducted previously, but equipment used was usually not very sophisticated, and modern analytical techniques were not developed. One particularly interesting and more modern type of catalysts are the zeolites. Probably the best known catalyst of this type is the ZSM-5 which is known to convert methanol into gasoline fractions via dimethyl ether formation. One disadvantage of this catalyst is that fast reaction for small molecules take place within the cavities of the catalyst, but reaction of larger molecules are drastically reduced by diffusion limitations. For example, molecules with kinetic diameters larger than 1,3,5-trimethylbenzene will not have access to the internal cavities. However, there is evidence that larger molecules can react on the surface of these catalysts and that the whole molecule may not have to penetrate the cavities.

Other catalysts to be tested will include those containing cobalt, molybdenum and tungsten. In particular, a version of the CoMo/AlO catalyst used for hydrodesulphurisation of petroleum will be studied. This catalyst is "sulphided" for petroleum treatment, but it may not be necessary to do this for oxygenated feedstocks. Both types of catalyst have been reviewed by Prof. Kaliaquine at Université Laval.

The second part of the study will involve the behaviour of the wood oils under cracking conditions. The oils contain some fairly high molecular weight material as indicated by distillation characteristics, and to be of use this material should be broken down into smaller molecules. However, all the oils, both catalytic and non-catalytic, have considerable oxygen contents. As a result of this, high temperature cracking favours water formation, with a reduction in the hydrogen carbon ratio and the formation of char. Coke formation on catalyst surface rapidly blocks the pores and surface and renders the catalyst inactive.

A laboratory-scale cracking unit, similar to one existing at the research laboratory of a major petrochemical company, has been constructed. Oils can be introduced onto a heated catalyst bed using a motor-driven syringe. Cracked liquid products are condensed and collected for analysis. Gaseous products are collected over brine and can be quantitatively analysed using a special dual column gas chromatograph. Preliminary studies on two cracking catalysts show that carbonisation is quite heavy when wood oil is used. The objective of the study will be to determine if catalytic cracking is a feasible first step in oil upgrading or whether a step such as deoxygenation should precede the cracking procedure. The two studies are thus very closely related, for if cracking cannot precede deoxygenation, fairly high molecular weight material may have to be deoxygenated, and this has significance for the types of deoxygenation catalysts which may be used.

CONTINUED

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$12,240			$12,240

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 406

TITLE Development of Analytical Techniques for Liquefaction Processes

CONTRACT # 31926-3-5040(OST83-00357)

CONTRACTOR University of Sherbrooke
Sherbrooke, Quebec
J1K 2R1

PRINCIPAL INVESTIGATOR E. Chornet

PROGRAM IDENTIFICATION 4.3.6.8
Biomass Conversion Technologies/
Oil Production-Liquefaction

DURATION February 1984 - February 1986

COST $92.376

SPONSOR Bioenergy Program
National Research Council

SCIENTIFIC AUTHORITY R.P. Overend
National Research Council
Canada
Bldg R-105 Rm 135
Ottawa, Ontario
K1A 0R6
Tele.: (613) 993-1342

OBJECTIVE

(1) Characterize the families of chemical products produced during the different stages of the thermoconversion.
(2) Characterize the monomers, oligomers and polymers within the same "family".

DESCRIPTION

(1) Develop methods for the analysis of the liquid products using G.C., H.P.L.C., S.E.C, 1C and 'H.N.M.R., Extractive Techniques, S.E.S.C., Classical and simulated distillations.
(2) Develop methods for the analysis of the solid products using T.G.A., D.T.A., D.S.C., with microscopy (O.M., T.E.M., S.E.M.), wet analytical tests and F.T.I.R.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1984-86	$92.376			$92.376

REPORTS

STATUS AND COMMENT

Work underway

R.P.O. 26/11/84

PROJECT DATA SHEET #	409	**PROGRAM IDENTIFICATION**	4.3.6.8 Biomass Conversion Technologies/ Oil Production-Liquefaction
TITLE	Conference on the Upgrading of Biomass at Sherbrooke Septembre 1983	**DURATION**	May 1983 - September 1983
CONTRACT #	31926-3-0068(05U83-00025)	**COST**	$4,730
CONTRACTOR	University of Sherbrooke Sherbrooke Quebec J1K 2R1	**SPONSOR**	Bioenergy Program National Research Council
PRINCIPAL INVESTIGATOR	E. Chornet	**SCIENTIFIC AUTHORITY**	R.P. Overend National Research Council Canada Building R-105, Rm 135 Ottawa (Ontario K1A 0R6 Tl.: (613) 993-1342

OBJECTIVE

To organize and provide facilities for the 3rd specialists liquefaction experts workshop to be held at the University of Sherbrooke on the 28 & 29th September, 1983. Additionally, the proceedings of the workshop will be prepared and sent to all participants and residual copies will be delivered to the National Research Council.

DESCRIPTION

The contractor shall be responsible fot the following:

(i) Provide facilities for the workshop in keeping with the standards required for scientific conferences (projectors, screens, microphones, etc.)
(ii) Making a block hotel reservation of or approximately 30 rooms at a Sherbrooke hotel (Le Baron) for the nights of the 28, 29 and 30th of September, 1983.
(iii) Make the necessary arrangements for visits to those laboratories at the Univertsity of Sherbrooke carrying out work on biomass upgrading.
(iv) Preparation of proceedings of the meeting.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983/84	$4,730			$4,730

REPORTS

Final Reports received May 1984 and published by NRCC under NRCC # 23130 "Comptes rendus de l'atelier de travail sur la liquefaction de la biomasse".

STATUS AND COMMENT

Project 31926-3-0068 completed

84/12/06

PROJECT DATA SHEET # 415

TITLE Catalytic Refining of the Products Obtained from the Liquefaction of Biomass and Peat

CONTRACT # Strategic Grant

CONTRACTOR
University of Sherbrooke
Dept. of Chemical Engineering
Sherbrooke Quebec
J1K 2R1

PRINCIPAL INVESTIGATOR E. Chornet

PROGRAM IDENTIFICATION 4.3.6.8 Biomass Conversion Technologies/ Oil Production-Liquefaction

DURATION November 1983 - November 1986

COST $168,800

SPONSOR Natural Sciences and Engineering Research Council

OBJECTIVE

1. The catalytic refining of products obtained from the liquefaction of biomass and lignin.
2. The development of a shear, jet reactor to break down macromolecules.
3. The use of various catalysts for the catalytic process.
4. The application of a new catalytic reactor for this process.
5. The characterization of the products obtained from the hydrogenation.

DESCRIPTION

(1) Preparation and characterization of the feedstock obtained using existing equipment by intergral liquefaction and a fractionation process to obtain lignin.
(2) Design construct and test a continuous catalytic refining reactor.
(3) Evaluation of the process using a series of three reactors to determine critical characteristics of the continuous reactor. The products from each stage will be characterized.
(4) Using the continuous reactor, long term tests will be carried out to evaluate the process and the products analyzed. Additionally, the products will be distilled in order to obtain pure fractions.
(5) An engineering analysis and assessment of the process will be carried out.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1983-84 1984-85 1985-86	$56,800 $56,800 $55,200			$ 56,800 $113,600 $168,800

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 71

TITLE Supercritical Fluid Extraction of Poplar Wood in a Continuous Liquefaction Unit

CONTRACT # KL229-9-7045 C51

CONTRACTOR
B.C. Research
Division of Applied Chemistry
3650 Wesbrook Mall
Vancouver, B.C.
V6S 2L2

PRINCIPAL INVESTIGATOR
J. Howard
Tel.: (604) 224-4331

PROGRAM IDENTIFICATION
4.3.6.8
Biomass Conversion Technologies/
Chemical Feedstocks

DURATION April 1979 - March 1984

COST $270,913

SPONSOR Energy, Mines & Resources

SCIENTIFIC AUTHORITY
A.J. Dolenko
Conservation & Renewable
Energy Mines & Resources
460 O'Connor Street
Ottawa, Ontario
K1A 0E4
Tele.: (613) 995-9447

OBJECTIVE

To attempt the extraction of essential oils, naval stores and lignins from poplar woods using gases at very high pressures at just above their critical temperatures and by such means save energy relative to the more conventional methods of extraction and also to maximize yield and minimize decomposition often associated with such methods.

DESCRIPTION

Forest product substrates will be contacted with various gases at very high pressures and at temperatures slightly above their critical points. The gases chosen for extraction will be those which are thought to show the most affinity for the desired extract. Thus polar gases are more likely to have a greater positive effect on the vapour pressure of a polar extractive than a non polar gas. The "solubilized" extractives will be recovered from the gas phase upon release of the pressure in a separate chamber. Equipment design will be based to some extent upon experience gained in the supercritical gas extraction of coal.

First a literature search will be carried out to determine whether supercritical gas extraction has received attention in the isolation of or modification of forest product chemicals. Next a laboratory investigation will be carried out on extraction of non polar essential oils from foliage via supercritical gas extraction, retaining the residues for possible consideration as animal feeds. Thirdly the relatively non polar volatile oils including turpentine, fatty and resin acids (naval stores) and steroids from fresh wood will be extracted using gases at high pressures limiting the wood species chosen for the study to those of commercial importance in western Canada. Next the polar lignin extractives occuring in wood and bark will be examined, which materials because of their relatively low volatility and frequent chemical instability, will represent the greatest challenge to supercritical gas extraction.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1979-80	$ 44,218			$ 44,218
1980-81	$ 83,480			$127,698
1981-82	$103,000			$230,698
1982-83	$ 9,145			$239,843
1983-84	$ 31,070			$270,913

CONTINUED

REPORTS

HOWARD J., "Supercritical Gas Extraction of Chemicals from Forest Products". March 1980 (Interim report)
McDONALD E.C., HOWARD J., BENNETT B., "Supercritical Gas Extraction of Chemicals from Forest Products". Phase II, June 1981 (Interim report)
McDONALD E.C., HOWARD J., BENNETT B., "Chemicals from Forest Products by Supercritical Gas Extraction". Phase III, Final Report.
(Available from ENFOR Secretariat or Energy Library)

STATUS AND COMMENT

Project Complete 84/12/03

PROJECT DATA SHEET # 418

TITLE By-products from Sulphite Pulping

CONTRACT # Strategic Grant

CONTRACTOR McGill University
Chemistry Department
Montreal, Quebec
H3A 2A7

PRINCIPAL INVESTIGATOR H.I. Bolker
N.G. Lewis
G. Just

PROGRAM IDENTIFICATION 4.3.6.9
Biomass Conversion Technologies/
Chemical Feedstocks

DURATION November 1983 - November 1986

COST $183,000

SPONSOR Natural Sciences and Engineering Research Council of Canada

OBJECTIVE

Although shifts towards different pulping processes and wood species have occurred in eastern Canada during the past decade, research on the possible utilization of the associated waste solubilized wood components has lagged. We propose to apply our newly developed hplc technique to the separation of those components, and with the cooperation of commercial organizations, to test the application of the fractions for end-uses such as oil-drilling, concrete plasticization and composite board manufacture.

DESCRIPTION

Phase I

Wood will be pulped under various new pulping process conditions (e.g. high-yield sulphite, alkaline sulphite/AQ, etc.) and methods will be developed for separating the novel individual lignin and hemicellulose components. Methodology used will include hplc, gel permeation chromatography, electrophoresis, extraction and dialysis. Other chromatographic techniques will be utilized as required.

Chemical characterization of the resolved components will require the acquisition of spectroscopic data (1H & 1C, nmr, uv, ir, ms), elemental analysis and melting point determinations, etc.

The physical data to be recorded for resolved components will include molecular weight distributions, surface activity measurements (i.e., surface and interfacial behaviour as a function of temperature, pH, and ion concentration), electrophoretic mobility and viscosity.

Phase II

Optimal removal of the desired lignin and hemicellulose materials will be achieved by variations of (i) pulping chemical charge, (ii) temperature of cooking, and (iii) specific processing steps (including time and pretreatment, etc.). The effect of pulping catalysts present during pulping and the role of the wood resource, i.e., softwood vs. hardwood, will also be evaluated.

Clearly, the experiments described above must not affect the properties of the pulp obtained in any detrimental way.

In addition, conditions ensuring the stability of spent pulping solution components, during isolation and handling procedures, will be investigated.

Phase III

This will require fractionation of these spent liquor components in gram quantities.

Phase IV

We propose to elucidate the bond-breaking processes which result in the release of these well-characterized ex-wood components, and to ascertain the morphological origin of such substances. This will require interpretation of the chemical and spectroscopic data obtained from (i) whole wood, (ii) the solubilized lignin and hemicellulose components, and (iii) the resulting pulp. This shall provide a more detailed understanding or our present knowledge of delignification.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$61,000			$ 61,000
1984-85	$61,000			$122,000
1985-86	$61,000			$183,000

CONTINUED

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 419

TITLE Enhanced Oil Recovery Using Lignin Waste Products

CONTRACT # Strategic Grant

CONTRACTOR
University of Ottawa
Chemical Engineering Dept.
Ottawa, Ontario
K1N 9B4

PRINCIPAL INVESTIGATOR
V. Hornof
G. Neale

PROGRAM IDENTIFICATION
4.3.6.9
Biomass Conversion Technologies/ Chemical Feedstocks

DURATION November 1983 - November 1986

COST $108,000

SPONSOR
Natural Sciences and
Engineering Research
Council of Canada

OBJECTIVE

To identify the active component(s) in lignosulfonates which render them particularly effective in enhanced oil recovery schemes;
To develop ways of improving the quality of lignosulfonates for use in oil recovery operations, and to reduce the amount of petroleum sulfonate required;
To ultimately test these lignosulfonate derivatives in a full-scale enhanced oil recovery trial in Western Canada.

DESCRIPTION

The following main lines of research will be followed in the immediate future:

i) A detailed study to identify the most active component(s) in spent sulfite liquors to determine whether lignosulfonates are more effective in their raw or refined forms, and to determine the effects of lignosulfonate molecular weight. This work is being carried out in close collaboration with the Pulp and Paper Research Institute of Canada, who are supplying us with fractionated lignosulfonate samples of known composition which have excellent surfactant properties. It is anticipated that this work will lead to the development of modified lignosulfonates which are tolerant to the high reservoir salinities typical of many Canadian reservoirs, and which are effective in recovering oil when used in the complete absence of petroleum sulfonates. It is then intended to actually carry out a full-scale tertiary oil recovery displacement operation in a Saskatchewan field.

ii) A detailed study of the effects of surfactant solution properties (especially interfacial tension and viscosity) on viscous fingering, and on the coalescence behaviour of oil droplets, in real petroleum reservoirs.
Viscous fingering is one of the most troublesome phenomena associated with oil recovery schemes in practice and, although widely documented, is poorly understood. Fingering leads to early surfactant "breakthrough" with consequent low oil recoveries. Coalescence phenomena control the rates at which oil droplets join together to form a bulk phase after being dispersed during a low interfacial tension displacement, and are likewise poorly understood.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1983-84	$40,000			$ 40,000
1984-85	$34,000			$ 74,000
1985-86	$34,000			$108,000

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 460		**PROGRAM IDENTIFICATION**	4.3.6.9 Biomass Conversion Technologies/ Chemical Feedstock
TITLE	A Business Plan for the Production of Butanol from Waste Agriculture Products	**DURATION**	April 1983 - March 1985
CONTRACT #	E2195 EL26	**COST**	$70,000
CONTRACTOR	R.F. Webb Corp. Ltd. 1011-5 Prince of Wales Dr. Ottawa, Ontario K2C 3K1	**SPONSOR**	Agriculture Canada
PRINCIPAL INVESTIGATOR	R.F. Webb	**SCIENTIFIC AUTHORITY**	E. Manolakis Engeering & Statistical Research Branch Agriculture Canada Engeering Bldg #94 C.E. Farm Ottawa, Ontario K1A OC6 Tele.: (613) 995-9671

OBJECTIVE

To formulate a technical and business plan for the commercial production of 500,000 gal/yr of butanol-acetone-ethanol at a site in PEI using cheese whey and cull potatoes.

DESCRIPTION

Using the expertise of D.R.F. (Biotechnology and Alternate Fuel Use Centre), University of McGill (Dept. of Chem. Eng.), J. Stone Assoc. and R.F. Webb Corp. Ltd. the business plan will include:

1. Assessment of butanol fermentation and recovery technology and process economics and recommend process and equipment for the proposed commercial plant.
2. Evaluations of feedstock available at Summerside, P.E.I. and at other selected Canadian locations in terms of continuity of supply.
3. Market analysis of the fermentation products and marketing opportunities for the P.E.I. plant and equipment manufacture.
4. Evaluation of the use of butanol and other liquid byproducts in transportation and farm machinery.
5. Total economic analysis to be modeled by computer to accommodate sensitivity analyses.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1983-84	$23,000			$23,000
1984-85	$47,000			$70,000

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 184

TITLE Characterizations of Pyrolysis Oils from Continuous flash pyrolysis of wood

CONTRACT # K1229-1-4122(OSU83-00015)
C-223

CONTRACTOR University of Waterloo
Dept. of Chemical Eng.
Waterloo, Ontario.
N2L 3G1

PRINCIPAL INVESTIGATOR D.S. Scott

PROGRAM IDENTIFICATION 4.3.6.11
Biomass Conversion Technologies/ Pyrolysis.

DURATION April 1981 - July 1984

COST $291,002

SPONSOR Energy, Mines & Resources

SCIENTIFIC AUTHORITY A.J. Dolenko
Conservation & Renewable
Energy, Mines & Resources
460 O'Connor Street
Ottawa, Ontario
K1A 0E4
Tele.: (613) 995-9447

OBJECTIVE

To design, construct, and test equipment for continuous flash pyrolysis of wood.

DESCRIPTION

1. Construction of a cold flow unit of glass and acrylic, testing of circulation loops in cold flow.
2. Design and construction of a 1kg/h continuous flash pyrolysis unit.
3. Determination of optimal yields and conditions, including tests with and without catalysts, using aspen poplar.
4. Further tests on one or two additional softwoods, bark twigs etc. at near optimal conditions.
5. Combustion tests, characterization of products.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1981-82 1982-83 1983-84	$ 94,353 $135,874 $ 60,775			$ 94,353 $230,227 $291,002

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 264		**PROGRAM IDENTIFICATION**	4.3.6.11 Biomass Conversion Technologies/ Pyrolysis
TITLE	An Investigation of the Fast Pyrolysis of Wood and its Components using the Ultrapyrolysis Process	**DURATION**	January 1983 - December 1985
CONTRACT #	31155-2-2647 (OSU82-00285)	**COST**	$240,471
CONTRACTOR	University of Western Ontario Room 101 Stevenson Lawson Building London, Ontario NOA 5B8	**SPONSOR**	Bioenergy Program National Research Council
PRINCIPAL INVESTIGATOR	M.A. Bergougnou Dept. of Chemical Eng.	**SCIENTIFIC AUTHORITY**	W. Graham National Research Council Montreal Road Building M-12 Room 343 Ottawa, Ontario K1A OR6 Tele.: (613) 993-9255

OBJECTIVE

1. Assess the fast pyrolysis research to date relative to Ultrapyrolysis.
2. Characterize the production of chemical intermediates as a function of various experimental variables during the fast pyrolysis of wood and its components.
3. Derivation of kinetic equations suitable for design and performance equations.
4. Prepare detailed designs for a fast pyrolysis pilot plant and a commercial prototype.

DESCRIPTION

Phase I A literature survey consisting of 1) characterization of the concept of fast pyrolysis and its relationship to other thermochemical conversion processes, and; 2) identification of major fast pyrolysis research programs and a summary of equipment, feedstocks, experimental parameters and results will be conducted.

Phase II The experimental program will consist of initial equipment design modifications and maintenance along with the actual research using biomass feedstocks.

Phase III Design of pilot plant and a commercial prototype.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1983	$81,362			$ 81,362
1984	$80,680			$162,042
1985	$78,429			$240,471

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET #	318	**PROGRAM IDENTIFICATION**	4.3.6.11 Biomass Conversion Technologies/ Pyrolysis
TITLE	Study of Liquid Fuels from the Flash Pyrolysis of Agricultural Biomass	**DURATION**	June 1982 - June 1983
CONTRACT #	01916-2-EL18 (OSU82-00126)	**COST**	$34,000
CONTRACTOR	University of Waterloo Dept. of Chemical Eng. Waterloo, Ontario N2L 3G1	**SPONSOR**	Agriculture Canada (Liquid Fuels Task)
PRINCIPAL INVESTIGATOR	D.S. Scott	**SCIENTIFIC AUTHORITY**	E. Manolakis Engineering & Statistical Research Institute Agriculture Canada Central Experimental Farm Ottawa, Ontario K1A 0C6 Tel.: (613) 995-9671

OBJECTIVE

To determine the optimum conditions for flash pyrolysis of agricultural feedstocks using a bench scale pyrolyzer. To prepare sufficient quantities of liquid products to facilitate product combustion and process performance tests and evaluate the chemical constituents in order to identify some possible ways of upgrading.

DESCRIPTION

1. To determine flash pyrolysis conditions giving maximum liquid yields for two or more common cellulosic agricultural materials (wheat straw, corn stover or others).
2. To prepare sufficient quantity of liquid products in a 3 kg/h continuous unit to allow combustion tests, as well as process unit performance tests.
3. To evaluate the chemical characteristics of the liquid products and to attempt some simple chemical upgrading and evaluation such as:
   a) liquid or vapour phase hydrogenation/cracking;
   b) detoxification of carbohydrates for further hydrolysis to fermentable sugars and;
   c) improve the characteristics of the liquids as a heating fuel (e.g. viscosity reduction).

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1982-83 1983-84	$24,000 $10,000			$24,000 $34,000

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 326

TITLE Economic Evaluation of the Gas Yields from a Plasma Pyrolysis Gasification System using Wood-Based Fuels

CONTRACT # KN107-2-4131 (DSS82-00027)
C-293

CONTRACTOR
Resorption Canada Ltd.
2465 Stevenage Drive
Ottawa, Ontario
K1G 3W2

PRINCIPAL INVESTIGATOR A. Tsangaris

PROGRAM IDENTIFICATION 4.3.6.11
Biomass Conversion Technologies/Pyrolysis

DURATION May 1982 - October 1984

COST $98,525

SPONSOR Energy, Mines & Resources

SCIENTIFIC AUTHORITY
A.J. Dolenko
Conservation & Renewable
Energy, Mines and Resources
460 O'Connor Street
Ottawa, Ontario
K1A OE4
Tele.: (613) 995-9447

OBJECTIVE

To optimize the gas yields from a plasma pyrolysis facility for various representative wood-based fuels and study the economic viability of a commercial scale wood gasification system using plasma heat. Optimization will centre on maximization of the volume and calorific value of the output gas (for direct use as a fuel) and a maximization of the quantity of particular constituents (for use as a synthesis gas).

DESCRIPTION

Two different types of biomass fuels of varying moisture content will be pyrolysed. For each condition a measured amount of biomass will be pyrolyzed at different temperatures and steam injection rates. Also gas chromatography and residual solids analysis will be conducted to yield energy and mass balances. The pyrolysis process will be optimized to produce the optimum gas yields at the lowest operating costs for each of the five fuel materials. Production capital and operating costs will be estimated for commercial application.

The tests will include two types of fuel, namely hogged fuel at moisture contents of 12% and 62% and crushed poplar. A total of 60 runs (20 runs for each different type of fuel or moisture content) will be performed as shown below:

Fuel Type	Moisture Content	Total Runs
Hogged Fuel	62% (as received)	20
	12%	20
Crushed Poplar	(as received)	20
TOTAL RUNS		60

At the commencement of the experiment runs will be at temperatures 800, 1000, 1200 and 1400C. Approaching optimization, run temperatures will be 1000, 1100 and 1200C plus one temperature chosen from the results to enable us to complete the curve and pinpoint the optimum processing conditions.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1982-83 1983-84	$61,325 $37,200			$61,325 $98,525

REPORTS

Resorption Canada Limited, "Research on Gasification of Wood in a Plasma Pyrolysis Unit," December 1983, ENFOR project C-293

STATUS AND COMMENT

PROJECT DATA SHEET # 328

TITLE
Detailed Design, Construction and Operation of a Vacuum Pyrolysis Process Development Unit (PDU)

CONTRACT #
KN107-1-4606 (DSU82-00005)
C-326

CONTRACTOR
University of Sherbrooke
Sherbrooke, Québec
J1K 2R1

PRINCIPAL INVESTIGATOR
C. Roy

PROGRAM IDENTIFICATION
4.3.6.11
Biomass Conversion Technologies/Pyrolysis

DURATION
April 1982 - June 1984

COST
$399,627

SPONSOR
Energy, Mines and Resources

SCIENTIFIC AUTHORITY
A.J. Dolenko
Conservation & Renewable
Energy, Mines and Resources
460 O'Connor Street
Ottawa, Ontario
K1A OE4
Tel.: (613) 995-9447

OBJECTIVE

1. To develop at the PDU level in a continuous process, the vacuum pyrolysis technology designed and checked successfully at the laboratory level.
2. To conduct the appropriate engineering studies at the technology level (e.g. handling of solids, heat transfer, cooling and recovery of organic vapors, mass transfer, etc. . .).
3. To determine the mass and energy budget, and thermal efficiency of the process.
4. To refine and characterize the pyroligneous distillate. Aside from our own samples, tars from conversion proceses studied in other Canadian laboratories will be characterized in order to compare the effectiveness of our technique.
5. To determine the economic value for the vacuum pyrolysis process.

DESCRIPTION

The proposed PDU assembly will have the following main characteristics:

1. traditional auger-type feed system - Granulometry: variable, from wood particles to pieces of the size of chips;
2. multiple-hearth furnace modified to operate at a lower pressure - the heating will be allothermic (external), either based on a eutectic salt-type heat carrier (inexpensive) or by electric heating (more costly) - the proposed maximum capacity will be 1 kg/h;
3. vapor cooling system, adjustable for each of the furnace hearths;
4. pegasus-type batch distillation column.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1982-83 1983-84	$138,510 $261,117			$138,510 $399,627

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 529

TITLE	Electrical Discharge Flash Pyrolysis of Biomass
CONTRACT #	KN107-1-4605 (OSU82-00043) 23216-3-6334 (OS183-00268) C-334
CONTRACTOR	University of Western Ontario Stevenson-Lawson Building Chemical Engineering Room 101 London, Ontario N6A 5B8
PRINCIPAL INVESTIGATOR	J.M. Beeckmans
PROGRAM IDENTIFICATION	4.3.6.11 Biomass Conversion Technologies/ Pyrolysis
DURATION	May 1982 - March 1984
COST	$46,261
SPONSOR	Energy, Mines and Resources
SCIENTIFIC AUTHORITY	R.P. Overend National Research Council Division of Energy Building R-105, Room 135 Ottawa, Ontario K1A OR6 Tel.: (613) 993-1342

OBJECTIVE

By using an electrical discharge flash pyrolysis of biomass, to determine the sample constitution (lignin, birch flour, cellulose), sample mass, initial water content, and composition of the gas surrounding the sample.

DESCRIPTION

Experiments consist of discharging a high voltage capacitor (320 Joules) through biomass samples held between two electrodes.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1982-83	$41,201			$41,201
1983-84	$ 5,060			$46,261

REPORTS

SIVELL A.N., BEEKMANS J.M. and WEBSTER A.K., "Electrical Discharge Flash Pyrolysis of Biomass," ENFOR Project C-334, December 1983.

STATUS AND COMMENT

The final report indicates that coupling the flash discharge to the biomass is more difficult than anticipated and that the technology is unlikely to evolve into anything more than a laboratory curiosity.

84/12/01

PROJECT DATA SHEET # 331

TITLE Ultrarapid Pyrolysis (Ultrapyrolysis) of Heavy Oils and Solid Fuels

CONTRACT # Strategic Grant

CONTRACTOR University of Western Ontario
Dept. of Chemical Engineering
London, Ontario
N6A 5B9

PRINCIPAL INVESTIGATOR M.A. Bergougnou

PROGRAM IDENTIFICATION 4.3.6.11
Biomass Conversion Technologies/
Pyrolysis

DURATION November 1981 - November 1984

COST $148,140

SPONSOR Natural Sciences and Engineering Research Council

OBJECTIVE

1. To develop a novel pneumatic contactor to mix, typically in 50 milliseconds, a hot finely divided solid heat carrier (thermofor) with a particulate feedstock for the ultra-rapid pyrolysis (ULTRAPYROLYSIS) of biomass, heavy oils, lignite, peat and any other carbonaceous feedstock, be it solid, liquid or even gaseous, in order to give ethylene, BTX building blocks and other chemical intermediates for the totally synthetic manufacture of petrochemicals and transportation fuels.
2. To develop an efficient cyclonic separator-stripper for the efficient removal and stripping, typically in 50 milliseconds, of the hot solid thermofor from the gaseous product before recycling the hot thermofor to the reheat step and sending the product gas to quench.

DESCRIPTION

The mixing of the thermofor and of the solid particulate feedstock has been studied on a cold plexigalss model, 10 cm. in diameter. The mixer is of a vortical contactor type (VORTACTOR). Two equal streams of thermofor are introduced into the barrel of the VORTACTOR as tangentially opposed jets. The biomass particulates are fed directly, in a downwardly direction, at the top of the VORTACTOR. The mixing of the three streams is studied downstream of the point of injection by a special "guillotine" sampler. The effects of the following variables on the mixing have been investigated: (a) thermofor and biomass solids loading; (b) thermofor and biomass inlet jet velocity; (c) vortactor body length; (d) biomass injector penetration into the barrel; (e) biomass injector shape. A new solid mixing index was developed which ranges from 0 to 1. Results indicate that a deflector under the biomass inlet of a chinese hat type gives best mixing indices. A mixing index of 0.9 could be obtained by optimizing experimental conditions. New improved mixers are being developed e.g. one using two jets of thermofor impinging at an angle on a central jet of biomass. This type of a mixer would allow simulation of particle mixing and heat transfer on a computer. The rapid cyclonic separator studied is of the uniflow underflow type. The body of the cyclone is 5 cm in diameter and 15.2 cm in body length. At an inlet velocity of 34.5 m/s, a solid to gas loading ratio of 5/1 (wt/wt), the separation efficiency was 99.4% on particulates around 80 microns in diameter. A factorial study is being carried out to optimize the cyclonic separator.
A mathematical model is in preparation staked out. Incorporating a stripping section into the cyclonic separator is being researched and is still at the conceptual stage.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1981-82	$49,380			$ 49,380
1982-83	$49,380			$ 98,760
1983-84	$49,380			$148,140

REPORTS

CONTINUED

STATUS AND COMMENT

PROJECT DATA SHEET #	411	**PROGRAM IDENTIFICATION**	4.3.6.11 Biomass Conversion Technologies/ Pyrolysis
TITLE	Development of an Atmospheric Pressure Flash Pyrolysis Process	**DURATION**	November 1983 - November 1985
CONTRACT #	Strategic Grant	**COST**	$158,320
CONTRACTOR	University of Waterloo Chemical Engineering Waterloo, Ontario N2L 3G1	**SPONSOR**	Natural Sciences and Engeering Research Council of Canada
PRINCIPAL INVESTIGATOR	D.S. Scott		

CONTINUED

OBJECTIVE

(1) To optimize the process for maximum energy efficiency, yield, product quality, and processing ease.
(2) To develop pre-treatment of the raw material as a means of controlling the nature of the products, using results of fundamental work reported in the literature (Shafizadeh and Stevenson, 1982).
DESCRIPTION)
The major variables to be investigated to optimize process performance for maximum liquid yield and quality are:

1. Temperature
2. Particle Size
3. Feed Rate
4. Moisture
5. Effects of Controlled Quench
6. Nature of Raw Material
7. Chemical Additives or Catalysts
8. Residence Time

Of these, temperature is the major variable investigated to date in the pilot plant, although not over a wide range. It has a strong effect on organic liquid yields, and the yield shows a maximum value over a fairly narrow temperature range. Further, the range at which maximum yields are obtained varies for each raw material e.g. 475C-525C for hardwoods, and 575-625C for straws. Hence, each raw material employed must be investigated to determine the effect of temperature on liquid yields. Temperature also affects product quality, for example, lower total yields but a higher proportion of light liquids are obtained at temperatures above the optimum. Together with residence time, it is probably one of the most important single variables.
Particle size is of great economic importance because of the very high energy cost of fine-grinding wood. Because flash pyrolysis processes must depend on rapid heat transfer, it is to be expected that larger particle sizes should mean longer residence times to achieve the same liquid yields. However, longer residence times may also cause loss of liquid by secondary reactions, but this effect may be partly offset by controlled rapid quenching, which initial tests in the pilot unit has shown to have some benefit. Residence time in a fluidized bed cannot be varied over wide limits. However, a range of perhaps four fold is possible.
Because of the inter-relationship of temperature, residence time, particle size and quenching on the organic liquid yield and liquid product quality, these parameters would be optimized for a given feed, probably poplar-aspen, by a factorial design of a series of experiments involving these four variables, together with further experiments for major variables.
A feed rate would exist beyond which heat transfer or kinetic effects would result in poorer yields, or beyond which mechanical problems might occur. Since the reactor capacity in terms of amount of feed which can be processed per unit time per unit volume of fluid bed, with satisfactory yields and operation, is a fundamental scale-up parameter, this variable will be investigated over ranges from low values to several kilograms/hr.
The use of a catalyst as the fluidizing solid medium, or in a secondary reactor, rather than inert sand is a possibility that has been explored only in a few preliminary bench scale experiments. In these tests, active nickel catalyst or alkali catalysts increase gas yields and decrease liquid yields. It would be desirable to promote decarbonylation, hydrogenation or dehydration to improve oil quality. A number of potential catalysts should be tried, particularly the zeolites because of their specific dehydration ability, and metallic decarbonylation catalysts. Initial evaluation would be done in the bench scale unit, with only the one or two showing the most potential being tested in the pilot plant.
Finally, in the present pilot plant cleanable surface condensers are used in order to allow total recovery of products, and so establish a material balance readily. Special packings and filters are necessary to remove tar aerosol from the product stream. A liquid scrubber would yield a hot oil from which heat could be recovered, and which would effectively scrub out aerosols. A portion of the oil product could be used as a scrubbing agent. The design, construction and testing of such a liquid scrubber is another necessary step in the evolution of this atmospheric flash pyrolysis process. Such a scrubber has already been described for use in recovery of liquids from coal pyrolysis (Che et al., 1982).
Two additional aspects relevant to process design and scale-up require investigation also when optimal operating ranges and conditions have been determined. These two are

1. Modelling of heat transfer processes in the fluidized bed, reactor.
2. Cold flow testing of a large diameter shallow fluid bed.

The current major emphases in this study are an investigation of catalytic action, in both liquid and vapour phases, on product quality; a major fundamental study of axial and radial mixing in shallow fluidized beds of solids of mixed densities; the development of a heat transfer model for the pyrolysis reactor; and a preliminary investigation of wood pre-treatment effects on the products of pyrolysis.

DESCRIPTION

CONTINUED

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1983-84	$83,310			$ 83,310
1984-85	$75,010			$158,320

REPORTS

SCOTT D.S. and PISKORZ J., "The continuous Flash Pyrolysis of Biomass," Can. J. Chem.Eng., 62, 404-412, 1984.

SCOTT D.S., PISKORZ J., and RADLEIN D., "Liquid Products from the Continuous Flash Pyrolysis of Biomass," Ind. Eng. Chem. Proc. Des. Devel. (in press 1984).

STATUS AND COMMENT

BIOENERGY - STRATEGIC STUDIES

Anaerobic Fermentation

Fermentation of Pentoses

Genetic Manipulation of Microbial Strains for Energy Production

Fluidizable Heat Storage

Molecular Models of Photosynthesis

Solar Energy Conversion via Photosynthesis Bacteria

Catalytic Synthesis

Membrane Applications in Gas and Liquid Seperations

Biochemical Production of Hydrogen

Oil - Bearing Microbes

Immobilized Cell Techniques for Fuel Production

Cellulase

PROJECT DATA SHEET # 61

TITLE Anaerobic conversion of cellulose to methane

CONTRACTOR National Research Council
100 Sussex Drive
Ottawa, Ontario. K1A 0R6

PRINCIPAL INVESTIGATOR S.M. Martin
Tel.: (613) 995-1921

PROGRAM IDENTIFICATION 4.3.7.1
Bioenergy Strategic Studies/
Anaerobic Fermentation

DURATION April 1978 - March 1984

COST $338,000

SPONSOR Division of Biological Sciences
Bioenergy Program
National Research Council

OBJECTIVE

To examine in detail the biochemical and microbiological aspects of the conversion of biomass to fuels and chemical feedstocks.

DESCRIPTION

A focussed fundamental study of microbial fermentations whereby an understanding of the physiology of microbes and the manipulation of their environment may be used to optimize production of fuels and chemical feedstocks from biomass:

1. Optimization of the production of ethanol from steam-exploded aspen wood by the anaerobe *Acetivibrio cellulolyticus*, particularly through an examination of the effect of perturbations in the chemical and physical environment of the fermentation system;
2. Simulation in an *in vitro* co-culture system of a natural ecosystem (anaerobic digester) wherein a variety of microbial types are able to convert cellulose to methane and thereby study the microbial interactions involved in methanogenesis;
3. Optimization of the microbial production of 2,3-butylene glycol to the extent that the process will be of economic significance.

FUNDING

FISCAL YEAR	SPONSOR	BIOLOGICAL SCIENCES		CUMULATIVE TOTAL
1980-81	$ 68,000	$ 35,000		$103,000
1981-82	$ 50,000	$ 25,000		$178,000
1982-83	$ 40,000	$ 40,000		$258,000
1983-84	$ 40,000	$ 40,000		$338,000

REPORTS

LAUBE V.M. and MARTIN S.M., "Effect of some Physical and Chemical Parameters on the Fermentation of Cellulose to Methane by a Coculture System". Can.J.Microbiol. 11: 1475 - 1408. NRCC No. 22640 (1983).

ARMSTRONG D.W., and Martin S.M., "Bacterial Fermentation of Cellulose: Effect of Physical and Chemical Parameters". Biotech. Bioeng. 25: 2567 - 2575 (1983).

LAUBE V.M., GROLEAU D., and MARTIN S.M., "2,3-Butanediol Production from Xylose and other Hemicellulosic Component by *Bacillus polymyxa*". Biotech. Lett. 6: 257 - 262. NRCC No. 22775 (1984)

STATUS AND COMMENT

PROJECT DATA SHEET # 209

TITLE
Anaerobic Production of Fuels, Chemicals, Cellulolytic Enzymes & Sugars from Cellulosic Biomass

CONTRACTOR
National Research Council
Biological Sciences
Sussex Drive
Ottawa, Ontario
K1A OR6

PRINCIPAL INVESTIGATOR
A.W. Khan
W.D. Murray

PROGRAM IDENTIFICATION
4.3.7.1
Bioenergy-Strategic Studies/
Anaerobic Fermentation

DURATION
April 1979 - March 1985

COST
$587,000

SPONSOR
Divison of Biological Sciences
Bioenergy Program
National Research Council
(Liquid Fuels Task)

OBJECTIVE

To develop efficient and fast single-step anaerobic processes for the conversion of cellulose and hemicellulose to fuels and chemicals and to develop an economical process for the production of cellulolytic enzymes and sugars from cellulose.

DESCRIPTION

The focus of the work is on the development of reactor systems which would allow fast conversion rates in spite of the slow rates of growth of these microorganisms. The need for intermittent contact between cellulose and individual bacteria has made it difficult so far to devise a system with dense populations of cellulolytic microorganisms. The work has led over the years to the isolation of several new mesophilic cellulolytic anaerobes, to the development of a relatively simple anaerobic digestion process for the production of cellulolytic enzymes and to the development of a single step process for the conversion of cellulosic waste to sugars.

FUNDING

FISCAL YEAR	SPONSOR	BIOLOGICAL SCIENCES		CUMULATIVE TOTAL
1979-80	$ 50,000			$ 50,000
1980-81	$ 60,000			$110,000
1981-82	$100,000			$210,000
1982-83	$140,000			$350,000
1983-84	$160,000			$510,000
1984-85	$ 48,000	$29,000		$558,000

REPORTS

KHAN A.W., "Lignocellulosic Biomass: Wood Residues Hold Promise as Fuel Chemical Source," Canadian Res., 17: 21-23, 1984.

MURRAY W.D., and ASTHER M., "Ethanol Fermentation of Hexose and Pentose Wood Sugars Produced by Hydrogen - Fluoride Solvolysis of Aspen Chips," Biotech. Lett., 6: 323-326, 1984.

GIULIANO C., ASTHER M., and KHAN A.W., "Comparative Degradation of Cellulose and Sugar Formation by Three Newly Isolated Mesophilic Anaerobes and Clostridium thermocellum," Biotech. Lett., 5: 395-398, 1983.

MURRAY W.D., SOWDEN L.C., and COLVIN J.R., "Bacteroides cellulosolvens sp. Nov., A Cellulolytic Species from Sewage Sludge," Int. J. Syst. Bact., 34: 185-187, 1984.

KHAN A.W., and MILLER S.S., "Use of a Newly-Isolated Strain of Clostridium butyricum for the Treatment of Ammonium-Bisulphite Waste Liquor", Process Biochem., 18: 29-30, 1983.

CONTINUED

STATUS AND COMMENT

These lab scale processes require substantial upgrading to become commercially feasible. More recently the feasibility of using steam and explosion decompressed wood as a substrate in anaerobic fermentation processes for the production of fuels and chemicals, has been studied. The formation of sugars by cellulolytic anaerobes , the primary step in direct conversion of cellulose, has been improved. These anaerobes form three major sugars namely cellobiose, glucose and xylose from lignocellulosic materials. For the conversion of all these sugars to ethanol in a single step a coculture consisting of *Zymomona anaerobias* and *Clostridium saccharolyticum* has been developed. Work is now underway with the objective of developing a one-step process improved in both the rate of cellulose hydrolysis and ethanol production.

A.W.K. 84/12/01

1979-84: Funding from both sources under "SPONSOR"

PROJECT DATA SHEET #	335	**PROGRAM IDENTIFICATION**	4.3.7.1 Bioenergy Strategic Studies/ Anaerobic Fermentation
TITLE	Acetone-Butanol Fermentation		
CONTRACT #	Strategic Grant	**DURATION**	November 1982 - November 1985
CONTRACTOR	University of Guelph College of Biological Science Guelph, Ontario K1G 2W1	**COST**	$113,726
		SPONSOR	Natural Sciences and Engineering Research Council
PRINCIPAL INVESTIGATOR	Cecil W. Forsberg		

OBJECTIVE

It is proposed to enhance the anaerobic acetone and butanol fermentation systems of Clostridium acetobutylicum and C. butylicum. The program will require the development of laboratory batch and continuous cultivation systems as a prerequisite to the scale-up of the process to pilot and industrial dimensions.

DESCRIPTION

It is proposed to screen Clostridium strains for the ability to use hemicellulose and cellulose for growth and solvent production. Fermentation products will be measured using gas chromatographic techniques. Characterization of the xylanase and cellulolytic enzyme activities of the strains selected for further study will be conducted. Once appropriate strains of bacterium have been selected, their cellulolytic activity and solvent producing ability will be tested against a number of carbohydrate sources.

FUNDING

FISCAL YEAR	SPONSOR	EQUIPMENT		CUMULATIVE TOTAL
1982-83	$33,173	$14,799		$ 47,972
1983-84	$32,904			$ 80,876
1984-85	$32,850			$113,726

REPORTS

STATUS AND COMMENT

Working in collaboration with L.N. Gibbins, Department of Microbiology. C.W.F.
84/12/07

PROJECT DATA SHEET # 116

TITLE Fermentation of Pentoses by Yeasts

CONTRACTOR
National Research Council
Molecular Genetics Group
Division of Biological Sciences
100 Sussex Drive
Ottawa, Ontario
K1A 0R6

PRINCIPAL INVESTIGATOR H. Schneider

PROGRAM IDENTIFICATION
4.3.7.2
Bioenergy-Strategic Studies/
Fermentation of Pentoses

DURATION April 1979 - March 1985

COST $428,386

SPONSOR
Division of Biological Sciences
Bioenergy Program
National Research Council

OBJECTIVE

To obtain yeasts that efficiently produce ethanol from the pentoses and hexoses in hydrolyzates of phytomass.

DESCRIPTION

Several yeasts are now available that can produce ethanol in yields exceeing 80% of theoritical from D-xylose in common laboratory media. However, yields are lower in hydrolyzates of potential industrial interest. The reasons are due, in part, to the presence of inhibitors that are produced during hydrolysis and to the accumulation of by-products. Current work is aimed at obtaining a bioconversion process that will work well at the industrial level. Substrates of industrial interest that are under investigation are spent sulfite liquor and a wood hydrolyzate produced using hydrofluoric acid. Two approaches are being pursued: one depends on the isolation of mutants of yeasts that produce higher amounts of ethanol more rapidly than wild-type strains, and the other depends on the development of processing conditions that lead to increased rate and yield of ethanol production.

FUNDING

FISCAL YEAR	SPONSOR	BIOLOGICAL SCIENCES		CUMULATIVE TOTAL
1979-80	$20,262			$ 20,262
1980-81	$30,993	$12,500		$ 63,755
1981-82	$72,331	$13,000		$149,086
1982-83	$37,800	$69,800		$256,686
1983-84	$31,700	$46,100		$334,486
1984-85	$56,600	$37,300		$428,386

REPORTS

SCHNEIDER H., "The Production of Ethanol from D-xylose by Yeasts", Royal Society of Canada - Proceedings of International Symposium on Ethanol from Biomass, Winnipeg, 508-524, October, 1982.

SCHNEIDER H., MALESZKA R., NEIRINCK L., VELIKY I.A., WANG P.Y., and CHAN Y.K., "Ethanol Production from D-xylose and Several other Carbohydrates by Pachysolen tannophilus and other Yeasts". Advances in Biochemical Engineering, 27: 57-71, 1983.

SLAPACK G., EDEY E., MAHMOURIDES G., and SCHNEIDER H., "Ethanol from Hexoses and Pentoses in Spent Sulfite Liquor." In "Biotechnology Advances", M. Moo-Young, editor, Pergamon Press (in Press).

MAHMOURIDES G., LEE H., MAKI N., and SCHNEIDER H., "Ethanol Accumulation in Cultures of Pachysolen tannophilus on D-xylose is associated with a transition to a state of low oxygen consumption." Bio/Technology, 1984 (in Press).

CONTINUED

STATUS AND COMMENT

Mutants of Pachysolen tannophilus have been isolated that produce higher yields of ethanol from xylose than the wild-type. The nature of the biochemical lesions responsible for this behavior are in the process of being identified, with a view to using the information to obtain even more efficient strains or better processing conditions.

Progress has also been made in understanding and in controlling the role that oxygen plays in the accumulation of ethanol. It is well known that aeration can be detrimental to ethanol yield from xylose, but that it is also required for growth. Pachysolen tannophilus was found to be able to enter a physiological state where it becomes a poor oxidizer of ethanol and of xylose, but during which it can produce ethanol efficiently. When the organism is in this state, ethanol is produced even when the rate of aeration is high. Efforts are underway to exploit the existence of this physiological state to obtain processing conditions that enhance the yield of ethanol.

84/12/04

PROJECT DATA SHEET #	332	**PROGRAM IDENTIFICATION**	4.3.7.2 Bioenergy Strategic Studies/ Fermentation of Pentoses
TITLE	High Yield Pentose Fermenting Yeasts for Immobilized Cell Bioreactors	**DURATION**	November 1982 - November 1985
CONTRACT #	Strategic Grant	**COST**	$70,475
CONTRACTOR	University of Western Ontario London, Ontario N6A 5B7	**SPONSOR**	Natural Sciences and Engineering Research Council
PRINCIPAL INVESTIGATOR	M.-A. Lachance Dept. of Plant Sciences		

OBJECTIVE

The objectives of the proposed project are to isolate and develop yeast strains capable of producing high yields of ethanol from D-xylose, and to develop appropriate immobilized cell bioreactor systems for the continuous fermentation of pentose rich materials to ethanol.
First, natural substrates likely to harbor yeasts able to ferment pentoses will be screened for such yeasts. If appropriate, promising strains will be subjected to mutagenesis or hybridization with the intent of improving rates and yields.
Optimization of immobilization media and bioreactor design will then follow, and the economic feasibility of large scale ethanol production assessed. It is anticipated that pentose utilization will result in marked improvements in the economic value of fermentation of lignocellulosic materials.

DESCRIPTION

Part I It is proposed to sample yeast habitats likely to harbor xylose fermenting yeasts, namely tree exudates, and trees undergoing fungal decay. The following two approaches will be used. A general elective liquid medium containing xylose as sole carbon source will be used to enrich samples for yeasts able to assimilate or dissimilate pentose sugars. Enriched populations will then be examined, as well as further subjected to selection on high xylose semi-solid media supplemented with increasing amounts of ethanol. Alternatively, samples will also be enriched first for alcohol tolerant fermenting yeasts in a high glucose, high ethanol medium. Subsequent selection on xylose plates will complete the isolation.
Part II (A. Margaritis) The most promising yeasts derived from the first part of the project will be subjected to the following experimentation with regard to cell immobilization. (A) The immobilization of cells using a number of different gel matrices will be investigated, in order to optimize the specific activity and the stability of the immobilized cells. (B) The immobilized cell system developed in (A) will be assessed in a number of different bioreactor types. These will include (i) batch, (ii) repeated batch, (iii) fixed-bed, (iv) continuous stirred tank with retained immobilized cells, and (v) fluidized bed. (C) The optimum immobilized cell bioreactor system will be selected to carry out economic feasibility studies for a commercial scale ethanol plant, using lignocellulosic waste materials. Particular emphasis will be placed on assessing the impact of pentose utilization on the overall economics of ethanol production.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1982-83	$16,715			$16,715
1983-84	$31,080			$47,795
1984-85	$22,680			$70,475

REPORTS

CONTINUED

STATUS AND COMMENT

Working in collaboration with A. Margaritis, Engineering Science.

84/12/07

PROJECT DATA SHEET # 334

TITLE Two Stage Process for Conversion of Xylose to Ethanol

CONTRACT # Strategic Grant

CONTRACTOR University of Waterloo
Chemical Engineering
Waterloo, Ontario
N2L 3G1

PRINCIPAL INVESTIGATOR C.W. Robinson

PROGRAM IDENTIFICATION 4.3.7.2
Bioenergy-Strategic Studies/
Fermentation of Pentoses

DURATION November 1982 - November 1985

COST $105,180

SPONSOR Natural Sciences and Engineering Research Council

OBJECTIVE

There is considerable interest in and potential for the use of fuel-grade ethanol as an alternative liquid fuel, especially when produced from forestry and agriculture lignocellulosic wastes which are relatively abundant in Canada. In order to achieve the maximum potential ethanol yield from such feedstocks, bioconversion of the pentose (xylose) in addition to the hexose (glucose) sugars is required. Present fermentation technology is based on conventional hexose-fermenting yeasts, which will not directly ferment xylose. A novel process is being developed in which xylose is converted to an intermediate chemical using an immobilized-enzyme bioreactor; the intermediate will be converted to ethanol in a packed-bed, immobilized hexose-fermenting yeast bioreactor. Several design and operating scenarios are being studied to determine the optimum process.

DESCRIPTION

The initial objectives of this study are:

1. to determine the kinetics of immobilized glucose isomerase (commercially prepared) with xylose as substrate
2. to conduct fermentations of xylulose to ethanol in free-cell cultures (stirred tank reactors) or in immobilized systems (packed-bed reactors) to evaluate yeast kinetics
3. to use preliminary process models to establish by simulation studies the best one or two overall schemes of immobilized bioreactors to most economically achieve the xylose-to-ethanol conversion
4. to construct a bench-scale version of the best one or two schemes from #3 above, and to run long-term stability studies on these systems.

Objectives (1) to (3) have been realized for systems corresponding to xylulose concentrations (ca. 40 g/L produced from 200 g/L xylose fed to the immobilized-enzyme reactor) and xylulose: xylose equilibrium conversion ratios (max. 24:6) available from 'conventional' enzyme reactor process conditions. Studies of surface immobilization of yeast cells on various support materials have been completed; beech wood chips have been found to be the most suitable column packing material. Preliminary runs are underway on the bench-scale immobilized enzyme/yeast bioreactor (Objective 4).

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1982-83	$32,700			$ 32,700
1983-84	$38,150			$ 70,850
1984-85	$34,330			$105,180

REPORTS

KABEL J.J., ROBINSON C.W., and MOO-YOUNG M., "Modelling of Xylose Fermentation to Ethanol by Sequential Isomerization and Fermentation," Biotechnol. Bioenerg. Symp. no. 13, 315-326 (1984)

CONTINUED

STATUS AND COMMENT

PROJECT DATA SHEET # 122

TITLE The Construction of Microbial Strains for Energy Production

CONTRACTOR
National Research Council
Div. of Biological
Molecular Genetics
Ottawa, Ontario
K1A OR6

PRINCIPAL INVESTIGATOR
V. Seligy
Tel.: (613) 992-6055

PROGRAM IDENTIFICATION
4.3.7.3
Bioenergy-Strategic Studies/
Genetic Manipulation of
Microbial Strains for
Energy Production

DURATION April 1979 - March 1984

COST $626,800

SPONSOR
Division of Biological Sciences
Bioenergy Program
National Research Council

OBJECTIVE

1. To provide a continuous watching brief that summarizes those recent findings, new techniques, and current trends in basic and applied genetic engineering that bear on the more efficient utilization of biomass in energy production.
2. To expand fundamental research on the expression, in yeast, of genes from other fungi.

DESCRIPTION

1. To conduct an extensive survey of literature dealing with recombinant DNA techniques in the utilization of biomass for energy production. To attend national and international conferences concerned with the role of biotechnology in energy production. To provide NRC's Division of Energy with a continuous watching brief concerned with trends and advances in this area.
2. The aim of this program is to use recombinant-DNA technology to extend the range of carbohydrate substrates that yeast can ferment to ethanol.

These projects are being carried out as part of an exploratory investigation of the usefulness of recombinant-DNA techniques in Biotechnology. Research is concerned, in particular, with the genetic engineering of yeast for more efficient utilization of biomass as a source of renewable energy.

Methods for transferring genes into yeast from other species or genera are now well established. However, the molecular basis of gene expression in yeast and other higher organisms is less well understood than in E. coli. The study of gene expression in yeast will emphasize genetic methods to increase specific enzyme synthesis and excretion by this organism. The enzymes of interest are amylase, B-glucosidase, exocellulases and endocellulases.

FUNDING

FISCAL YEAR	SPONSOR	BIOLOGICAL SCIENCES		CUMULATIVE TOTAL
1979-80	$10,000	$130,000		$ 10,000
1980-81	$10,000	$192,000		$150,000
1981-82	$ 8,500			$350,500
1982-83	$85,000	$191,300		$435,500
1983-84	$72,700			$626,800

REPORTS

The Molecular Genetics Group prepared a literature review of recombinant DNA techniques in biomass conversion and submitted a report on the state-of-the-art and progress review.

STATUS AND COMMENT

We contributed information to 3 meetings this year concerning expression of cellulars in yeast & bacteria. We have cloned two yeast genes which could serve as a yeast vector system. Global information indicates cellulare gene expression in yeast can occur but industry is not too anxious to develop for market.

84/12/06

PROJECT DATA SHEET #	199
TITLE	Novel Technology for Alcohol Production by Fermentation
CONTRACT #	Strategic Grant
CONTRACTOR	University of Saskatchewan Applied Microbiology and Food Science Saskatoon, Saskatchewan S7N 0W0
PRINCIPAL INVESTIGATOR	W.M. Ingledew
PROGRAM IDENTIFICATION	4.3.7.3 Bioenergy trategic-Studies/ Genetic Manipulation of Microbial Strains for Energy Production
DURATION	November 1980 - November 1983
COST	$102,762
SPONSOR	Natural Sciences and Engineering Research Council

OBJECTIVE

The overall objective of this study was to improve the economics of the production of alcohol to be used as an alternate energy source in automobiles as gasohol, to develop a starch substrate-based single cell protein (fodder yeast) product, and to use genetic manipulation to acheive these objectives.

DESCRIPTION

This project has emphasized research on the yeast *Schwanniomyces*, a starch degrading-alcohol producing yeast. We have examined its amylolytic capabilities and described in detail an isolated and purified-amylase and a glucoamylase. *Schwanniomyces* is one of a very few yeasts which produces both these enzymes as well as having some fermentative ability to make ethanol from distressed grains or potato starches.

We have also succeeded in derepressing wild type strains so that they produce 3 to 4 fold levels of both amylases. This level of enzymes or more will be required if this microbe is to become industrially important for alcohol production, amylase production or as a source of single cell protein. We have used conservative genetic techniques (protoplast fusion) to examine intrageneric fusion of *Saccharomyces* and *Schwanniomyces*, and interspecific fusion of 2 *Schwanniomyces* species with differend enzyme complements. Our aim has been to create superamylolytic yeasts capable of rapid fermentation of starch to ethanol. Although we have not yet succeeded in production of strains useable in industry, we think with what we now know, after suitable genetic work-up such a strain may be possible.

This work represents the first reports on the use of protoplast fusion in this genus and derepression of amylase enzymes in *Schwanniomyces*. A number of laboratories in Canada and the world are now also examining this microbe in detail.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1980-81	$33,000			$ 33,000
1981-82	$36,762			$ 69,762
1982-83	$33,000			$102,762

CONTINUED

REPORTS

CASEY G.P., DHAWALE M.D., and INGLEDEW W.M., "Novel Approaches to Starch and High Gravity Fermentations." Proceedings Fifth Bioenergy R&D Symposium (in press), 1984.

DHAWALE M.R., and INGLEDEW W.M., "Interspecific Fusion of *Schwanniomyces* Yeasts," Biotechnology Letters 5(12):825-830, 1983.

DHAWALE M.R., AND INGLEDEW W.M., "Starch Hydrolysis by Derepressed Mutants of *Schwanniomyces castellii*", Biotechnology Letters 5(3):185-190, 1983.

WILSON J.J., KHACHATOURIANS G.G., AND INGLEDEW W.M., "*Schwanniomyces*: SCP and Ethanol from Starch," Biotechnology Letters 4(5):333-338, 1982.

DHAWALE M.R., WILSON J.J., KHACHATOURIANS G.G., and INGLEDEW W.M., "Improved Method for Detection of Starch Hydrolysis," Applied and Environmental Microbiology 44(3) :747-750, 1982.

STATUS AND COMMENT

Working in collaboration with G.G. Khachatourians.

84/12/01

PROJECT DATA SHEET #	249	**PROGRAM IDENTIFICATION**	4.3.7.3 Bioenergy-Strategic Studies/ Construction of Microbial Strains for Energy Production
TITLE	Development of an Amylase Producing Yeast		
CONTRACT #	31155-9-0623 (OSX80-00027)	**DURATION**	June 1980 - June 1983
CONTRACTOR	National Research Council Div. of Biological Sciences Sussex Drive Ottawa, Ontario K1A OR6	**COST**	$1,154,665
		SPONSOR	Division of Biological Sciences Bioenergy Progam PILP National Research Council
PRINCIPAL INVESTIGATOR	V. Seligy A. Nasim J. Erratt	**SCIENTIFIC AUTHORITY**	V. Seligy Division Biological Sciences National Research Council Ottawa, Ontario K1A OR6 Tele.: (613) 992-6055

OBJECTIVE

To develop an amylase producing fermentation yeast.

DESCRIPTION

Task 1 The identification of suitable amylases and selection of specific strains for donor gene. The development of yeast cloning methods.
Task 2 The isolation of the donor gene, its amplification and insertion into host organism.
Task 3 Measure gene expression, & test for stability, growth & conversion efficiency to ethanol.
Task 4 Optimization of process, secondary strain selection and modification. Selection of final strain and pilot scale growth trials.
Task 5 "Beer" distillation optimization and pilot scale optimization. Large scale trials and commercial assessment.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1980-81	$298,200			$ 298,200
1981-82	$352,100			$ 650,300
1982-83	$410,700			$1,061,000
1983-84	$ 93,665			$1,154,665

REPORTS

PAICE M.G., DESROCHERS M., RHO D., JURASEK L., ROY C., ROLLIN C.F., DEMIGUEL E. and YAGUCHI M., "Two Forms of Endoglucanase from the basidiomycete Schizophyllum commune and their Relationship to other -1,4-Glycoside Hydrolases", Bio/Technology, 2: 535-539, June 1984.

STATUS AND COMMENT

This project was initially funded by the National Research Council, under PILP, and awarded to ENS BIO Logicals. The project has now been assumed by the National Research Council, Division of Biological Sciences.
Two genes have been cloned and one expressed in yeast. Some collaboration was initiated through PILP with Labatt's and two of their researchers are now in our labs.

84/12/01

PROJECT DATA SHEET # 250

TITLE
To Produce new Strains of Yeast via Genetic Engineering for Direct Conversion of Cellulose to Alcohol

CONTRACTOR
National Research Council
Division of Biological Sciences
Sussex Drive
Ottawa, Ontario
K1A OR6

PRINCIPAL INVESTIGATOR
V. Seligy
M. Yaguchi
G. Willick

PROGRAM IDENTIFICATION
4.3.7.3
Bioenergy-Strategic Studies/ Construction of Microbial Strains for Energy Production

DURATION
November 1980 - November 1983

COST
$1,072,452

SPONSOR
Division of Biological Sciences
Bioenergy Program
PILP
National Research Council

SCIENTIFIC AUTHORITY
V. Seligy
Molecular Genetics
Division Biological Sciences
National Research Council
Ottawa, Ontario
K1A OR6
Tele.: (613) 992-6055

OBJECTIVE

To produce new engineered yeast clones capable of converting cellulose into ethanol directly.

DESCRIPTION

1. Carry out organizational and sequential analysis of cloned genes;
2. Construct the vector hybrids with genes and transform genes into yeast;
3. Isolate DNA and m RNA from donors amd recipient (transformed) cells;
4. Develop yeast vectors and establish a screening method;
5. Test the effects of yeast for activity and stability of the enzymes;
6. Assay sugar and ethanol with substrates containing cellulosic materials;
7. Assess commercial viability.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1980-81	$ 68,621			$ 68,621
1981-82	$286,669			$ 355,290
1982-83	$391,867			$ 747,157
1983-84	$325,295			$1,072,452

REPORTS

SELIGY, V.L., BARBIER J.R., DIMOCK K.D., DOVE M.J., MORANELLI F., MOROSOLI R., WILLICK G.E. and YAGUCHI M., "Current Status in the Application of Recombinant DNA Technology in the Construction of Cellulolytic Yeast Strains", Proceedings of the Alko Yeast Symposium Helsinki 1983, ed. by M. Korhola and E. Vaisanen, Foundation for Biotechnical and Industrial Fermentation Research, 1 (1983): pp 167-185.

YAGUCHI M., ROY C., ROLLIN C.F., Paice M.G. and Jurasek L. "A Fungal Cellulase Shows Sequence Homology with the Acitive Site of Hen Egg-White Lysozyme", Biochemical and Biophysical Research Communications, Vol. 116, no. 2, pp 408-411, Oct. 1983.

MARGARITIS A., MERCHANT R. and YAGUCHI M., "Xylanase, CM-Cellulase and Avicelase Production by the Thermophilic Fungus *Sporotrichum thermophile*, Biotech. Letters, Vol. 5, no. 4, 265-270, 1983.

DIMOCK K., JAMES A.P. and SELIGY V.L., "Molecular Cloning of the ADE1 Gene of *Saccharomyces cerevisiae* and Stability of the Transformants", Gene, 27(1983) 233-237.

CONTINUED

STATUS AND COMMENT

This project was initially funded by the National Research Council, under PILP, and awarded to the Ontario Paper Company (contract # 31155-9-0642). the project has now been assumed by the National Research Council, Division of Biological Sciences.

Clones for endoglucanase and -glucosidase genes have been isolated and are now being characterized for work in yeast. The endoglucanase gene has been expressed in *E.coli* at a level comparable to bacterial cellulose cloned in *E.coli*. Details of the secretion of the enzymes in both fungi and yeast have been examined (Seligy, Willick, Moranelli) The active site of cellulases has been predicted from the amino acid sequence in formation (Yaguchi).

84/12/01

PROJECT DATA SHEET #	340	**PROGRAM IDENTIFICATION**	4.3.7.3 Bioenergy-Strategic Studies/ Genetic Manipulation of Microbial Strains for Energy Production
TITLE	Cloning and Expression of Cellulase Genes		
CONTRACT #	Strategic Grant	**DURATION**	November 1982 - November 1985
CONTRACTOR	University of British Columbia Department of Microbiology Vancouver, British Columbia V6T 1W5	**COST**	$330,000
		SPONSOR	Natural Sciences and Engineering Research Council
PRINCIPAL INVESTIGATOR	R.C. Miller		

OBJECTIVE

Cloned cellulase genes, from Cellulomonas fimi ,will be transferred from the plasmid pBR322 to a plasmid in Bacillus subtilis. The intent is to develop bacterial strains which secrete the cellulases in large amounts. This means that the cloned genes must be linked to high level promoters of transcription, that the messenger RNA must be efficiently translated and that the host organism must be capable of transporting the enzymes.

DESCRIPTION

1. Transfer of genes to B. subtilis. The C. fimi cellulase genes have been cloned into the BamH1 site of pBR322. Thus, the first stage of the work will be to transfer the cloned fragments from the pBR322 derivatives to the BamH1 site of a B. subtilis vector.
2. Increased expression of cellulase Bacillus genes. Phage 29 has a strong promoter which is recognized by the B. subtilis RNA polymerase and is transcribed at a high level. The genes will be inserted down stream from this promoter at a Hind III site.
3. Transfer of genes to C. fimi. Conditions will be determined for transfer of this plasmid to C. fimi.
4. Genetic engineering of cellobiase. It is proposed to apply recombinant DNA techniques to the development of end-product resistant enzymes or achieve a method of end product (glucose) removal.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1982-83	$110,000			$110,000
1983-84	$110,000			$220,000
1984-85	$110,000			$330,000

REPORTS

STATUS AND COMMENT

Working in collaboration with D.G. Kilburn, R.A.J. Warren, Department of Microbiology. R.C.M.
84/12/06

PROJECT DATA SHEET # 407

TITLE Modification of Strains of *Streptomyces* using Genetic Engineering Techniques for Hyperproduction of Extra-cellular cellulases and xylanases

CONTRACT # Strategic Grant

CONTRACTOR
Université du Québec
Centre de recherche en bactériologie
Montréal, Québec

PRINCIPAL INVESTIGATOR
D. Kluepfel
R. Morosoli
R. Shareck

PROGRAM IDENTIFICATION 4.3.7.3
Bioenergy-Strategic Studies/
Genetic Manipulation of Microbial
Strains for Energy Production

DURATION November 1983 - November 1986

COST $175.500

SPONSOR Natural Sciences and Engineering Research Council of Canada

OBJECTIVE

DESCRIPTION

The principal object of this project is to develop a strain(s) of *Streptomyces flavogriseus* capable of producing large quantities of cellulolytic enzymes as well as hemicellulases. All of these enzymes are required for the development of an industrial process for the bioconversion of both lignocellulosics and biomass. The approach chosen for this project is to use genetic engineering techniques isolate those genes responsible for the biosynthesis of these enzymes and to optimize their expression in *S. flavogriseus*. It will be important and essential that these enzymes not only be produced in large quantities, but that they also be excreted into the culture medium in order that they be easily recovered and that they be produced in a continuous fermentation.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$58.500			$ 58.500
1984-85	$58.500			$117.000
1985-86	$58.500			$175.500

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 412		**PROGRAM IDENTIFICATION**	4.3.7.3 Bioenergy-Strategic Studies/ Genetic Manipulation of Microbial Strains for Energy Production
TITLE	Development of High Expression Plasmids for Saccharomyces cerevisiae		
CONTRACT #	Strategic Grant	**DURATION**	November 1983 - November 1986
CONTRACTOR	University of Concordia Biology Department Montreal, Quebec H3G 1M8	**COST**	$87,560
		SPONSOR	Natural Sciences and Engineering Research Council of Canada
PRINCIPAL INVESTIGATOR	R.K. Storms M.B. Herrington		

OBJECTIVE

Short Term Objectives: 1. Plasmids which enable the screening of yeast DNA for sequences which promote high levels of gene expression will be constructed.
2. These plasmids will be used to isolate sequences which effect high levels of expression. The sequences will be immediately useful for the construction of new hybrid genes which express commercially valuable gene products efficiently in yeast.
3. Provide an opportunity for graduate students, technicians and Post Doctoral fellows to learn yeast molecular biology and recombinant DNA technology.
Long Term Objectives: 1. Understanding of the role played by sequence 3' and 5' to the coding region of genes in determining efficiency of gene expression.
2. Construction using in vitro techniques, of mutations in regions both 3' and 5' to the coding region, which alter efficiency of gene expression and the detailed characterization of these should enable us to work towards an understanding of the basic mechanisms determining efficiency of gene expression

DESCRIPTION

A construction of plasmids useful for studying the role of sequences placed 3' and 5' to the coding region of lacZ on gene expression. The following construction will result in a plasmid which will allow us to readily insert different sequences at the 5' and the 3' ends of the coding region of the lacZ gene from E. coli. Since B-galactosidase, the gene product of the lacZ gene is easily measured we can easily determine the effect of a particular 5' or 3' flanking sequence on gene expression.

Plasmid pMC931 contains the lac operon without the 5' lac regulatory sequences. Since lacY and lacA are present and no unique restriction endonuclease site is present immediately 3' to lacZ sequences can not be readily inserted at the 3' end of lacZ. A recent publication giving the DNA sequence of the lacY and lacA regions shows the following strategy is possible (11). We will digest plasmid pMC931 with restriction enzymes EcoRI and Sau3A, and isolate from the digest the 421 base pairs (bp) fragment which carries a 51bp sequence corresponding to the C-terminal 17aa of B-galactosidase, the 54bp intra cistronic region and the 315bp corresponding to the N-terminal 106aa of the lac permease. Plasmid pBR322 will be digested with endonucleases EcoRI and BamHI, and the larger of the two fragments generated will be isolated. Since Sau3A and BamHI generate the same sticky ends the EcoRI-Sau3A fragment from pMC931 can be readily inserted into the large fragment of pBR322. The Sau3A site in lacY is flanked by a G on its 5, side and therefore the resulting plasmid will regenerate the BamHI site. We will then replace the EcoRI-SaLI fragment of pRS269 with the EcoRI-SaLI fragment of the new plasmid. Plasmid pRS269 carries the entire lac operon with lacZ expression controlled by the Yeast TMP1 gene's 5' regulatory region. The construction described above will replace the 3' terminal from pRS269 with a smaller fragment which carries the 3' end of lacZ but lacks most of lacY, all of lacA, and all of leu2. It also generates a unique BamHI site 370 base pairs from 3' end of lacZ and a unique SaLI site 640 base pairs from the 3' end of lacZ. In order to have a selectable marker for transforming yeast we will insert the leu2 gene of yeast (carried on a SaLI XhoI fragment) into the unique SaLI site.

The basic features of the new plasmid are: 1. It can replicate autonomously in both yeast and E. coli. 2. It carries selectable markers for yeast (leu2 gene) and E. coli (Apur and leu2 gene) 3. It has a unique site for the restriction endonuclease BamHI immediately 3' to lacZ. 4. It has a unique Hind III site for restriction endonuclease digestion immediately 5' to the lacZ gene. This plasmid will allow us to place lacZ under the regulation of different 3' and 5' regulatory sequences.

CONTINUED

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1983-84 1984-85 1985-86	$28,060 $29,500 $30,000			$28,060 $57,560 $87,560

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 417		**PROGRAM IDENTIFICATION**	4.3.7.3 Bioenergy-Strategic Studies/ Genetic Manipulation of Microbial Strains for Energy Production
TITLE	Upgrading of Lignin Using Biological Catalysts	**DURATION**	November 1983 - November 1986
CONTRACT #	Strategic Grant	**COST**	$150,856
CONTRACTOR	University of Sherbrooke Dept. of Microbiology Faculty of medicine Sherbrooke Quebec J1H 5N4	**SPONSOR**	Natural Sciences and Engineering Research Council
PRINCIPAL INVESTIGATOR	P. Chartrand C. Roy		

OBJECTIVE

To upgrade by depolymerization of lignin using a biological process.

DESCRIPTION

(1) Cloning of lignolytic genes from Trametes versicolor.
(2) Development of a biological system in which these genes would be expressed in large quantities.
(3) Establish reaction conditions for the modification of lignin using the product of these genes.
(4) Scale-up of the developed process for use in a bioreactor.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$53,414			$ 53,414
1984-85	$48,721			$102,135
1985-86	$48,721			$150,856

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET #	321
TITLE	A Study of Organic Photovoltaic Cells Based on Photosynthesis Pigments
CONTRACT #	Strategic Grant
CONTRACTOR	University of Québec Trois-Rivières, Québec G9A 5H7
PRINCIPAL INVESTIGATOR	R.M. Leblanc Centre de recherche en photobiophysique
PROGRAM IDENTIFICATION	4.3.7.5 Bioenergy-Strategic Studies/ Molecular Models of Photosynthesis
DURATION	November 1982 - November 1985
COST	$132,600
SPONSOR	Natural Sciences and Engineering Research Council

OBJECTIVE

To augment the efficiency and power of the organic photovoltaic cells by a better understanding of the photosynthetic constituents which could reduce the internal resistance of the system.

DESCRIPTION

In order to examine systematically the influence of the photosynthetic constituents on the photovoltaic properties of chlorophyll A at the multi-layer state, the following investigations are proposed:

1. the photovoltaic properties of the chlorophyll system A plus pheophytine A and the molar variations of the constituents
2. the photovoltaic properties of chlorophylls A & B
3. the photovoltaic properties of chlorophyll A plus plastoquinone
4. the photovoltaic properties of chlorophyll A plus lutein, a carotenoid pigment.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1982-83	$ 48,000			$ 48,000
1983-84	$ 42,300			$ 90,300
1984-85	$ 42,300			$132,600

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 117

TITLE Membrane Application in Gas and Liquid Separations

CONTRACTOR National Research Council
Division of Chemistry
Montreal Road
Ottawa, Ont. K1A OR6

PRINCIPAL INVESTIGATOR S. Sourirajan
Tel.: (613) 993-2455

PROGRAM IDENTIFICATION 4.3.7.8
Bioenergy-Strategic Studies/
Membrane Applications in
Gas and Liquid Separations

DURATION October 1979 - March 1984

COST $347,510

SPONSOR Bioenergy Program
Division of Chemistry
National Research Council

OBJECTIVE

1. To produce high purity hydrogen, high Btu pipeline fuel and/or synthesis gas from gas mixtures.
2. To recover alcohol in high concentrations from fermentation liquids.
3. To fractionate mixtures of organic liquids arising in petroleum processes.

DESCRIPTION

An equation applicable for the analysis of experimental gas permeation data has been developed in terms of Knudsen, slip, viscous and sorbed flow through membrane pores. The utility of the above equation for predicting single- and mixed-gas transport through membranes is being investigated. Using membranes made from a polyether imine sulfonourethane material, reverse osmosis separations of ethyl alcohol up to 79% have been accomplished from 10 wt.% ethyl alcohol-water feed solutions at 1000 psig. Using appropriate liquid chromatography data, the magnitudes of the interaction forces between alcohol and membrane material, and also the average pore sizes required for achieving different levels of ethanol separation in reverse osmosis are being estimated for different membrane materials.

Reverse osmosis separations of several inorganic and organic solutes in methanol solutions have been studied using cellulose acetate membranes. From liquid chromatography and reverse osmosis experiments, quantitative data on the interaction forces prevailing at the membrane material-methanol solution interfaces have been estimated. These data offer a physiochemical basis for reverse osmosis process design for the purification of industrial methanol. Further, fractionation of heptane-ethyl alcohol mixtures by permeation through cellulosic membranes is being investigated.

FUNDING

FISCAL YEAR	SPONSOR	DIVISION CHEMISTRY		CUMULATIVE TOTAL
1979-80	$18,510	$ 5,000		$ 23,510
1980-81	$51,000	$15,000		$ 89,510
1981-82	$51,000	$25,000		$165,510
1982-83	$37 000	$25,000		$227,510
1983-84	$80,000	$40,000		$347,510

CONTINUED

REPORTS

MINHAS B.S., MATSUURA T., and SOURIRAJAN, S., "Solvent Exchange Drying of Cellulose Acetate Membranes for Separation of Hydrogen-Methane Gas Mixtures," A.C.S. Symposium on Reverse Osmosis and Ultrafiltration, Philadelphia, August 26-30, 1984

FARNAND B., TALBOT F.D.F., MATSUURA T., AND SOURIRAJAN S., "Formation of Cellulose Membranes for Reverse Osmosis Separation of Water - Inorganic Solute, and Water - Organic Solute Systems," Proceedings fifth Bioenergy Seminar, National Research Council of Canada, Ottawa, (in press).

MINHAS B.S., MAZID M.A., MATSUURA T., and SOURIRAJAN S., "Formation of Cellulose Acetate Membranes for the Separation of Hydrogen - Methane Gas Mixtures," Proceedings of the Fifth Bioenergy Seminar, National Research Council Canada, Ottawa, (in press).

MAZID M.A., RANGARAJAN R., MATSUURA T., and SOURIRAJAN S., "Separation of Hydrogen - Methane Gas Mixtures by Permeation under Pressure through Porous Cellulose Acetate Membranes," Ind. Eng. Chem. Process Des. Dev. (in press).

STATUS AND COMMENT

PROJECT DATA SHEET #	434	**PROGRAM IDENTIFICATION**	4.3.7.8 Bioenergy-Fundamental Studies/ Membrane Application in Gas & Liquid Separations
TITLE	Membrane Fabrication, Testing and Evaluation		
CONTRACT #	05SR.31926-3-5048(OSR83-00129)	**DURATION**	March 1984 - March 1986
CONTRACTOR	Zenon Environmental Inc. 845 Harrington Court Burlington, Ontario L7N 3P3	**COST**	$161,004
		SPONSOR	Bioenergy Program National Research Council
		SCIENTIFIC AUTHORITY	R.P. Overend Division of Energy R&D National Research Council Building R-105, Rm 135 Ottawa, Ontario K1A OR6 Tele.: (613) 993-1342

OBJECTIVE

The context of this project is to support NRC in its desire to develop better membranes for the desired applications through the use of its fundamental pore transport theory. Specifically, this project has the following objectives;

i) To characterize cellulose membranes;
ii) To determine the potential of cellulose membranes for organic liquid separation and to relate membrane characteristics to organic separation.
iii) To determine the capability of aromatic polyamide membranes for alcohol separation on the basis of an understanding of the pore structure of such membranes.

DESCRIPTION

(1) Development of Cellulose Membranes and the Determination of the Average Pore Size and the Pore Size Distribution.
The object of this research is to correlate the conditions of cellulose membrane formation to the pore size distribution of membranes produced.
For this purpose, NRC will supply cellulose membranes and the Contractor will conduct RO experiments with respect to reference solutes necessary for the pore characterization under standard operating conditions.
All Reverse Osmosis (RO) experiments will be conducted with cells using aromatic and aliphatic hydrocarbons as well as polar organic compounds under conditions ranging up to 12 mega pascals (12 M Pa) pressure differential and temperature range of 5 to 65 C. See 2 and 3 below.

(2) Study of the Separation of Hydrocarbon and Other Organic Liquids by Cellulose Membranes.
The object of this research is to study the separation of organic liquids with membranes characterized in the first project.

(3) Study of Aromatic Polyamide Membranes for the Separation of Alcohol/Water Mixtures.
It is known that aromatic polyamide membranes exhibit one of the highest ethanol/water separation (ca 70% with 10% ethanol feed solution). The object of this research is to obtain the average pore size and pore size distribution which were found necessary by computation to achieve the separation of 90% with respect to the feed ethanol solution of 10%.

(4) The Contractor will fabricate an RO unit with test cells bases on the NRC design. the RO unit, including spares, will require:
- one pump
- twelve RO cells
- two accumulators
- three pressure regulators

(5) The dedicated Analytical Equipment requires:
- one carbon analyzer
- one refractometer
- one conductivity bridge
- one gas chromatograph.

(6) As for the data reported from the contract executor, they include;
a) temperature at which pure water permeation sample is collected,
b) temperature at which product solution sample is collected,
c) operating pressure,
d) solute separation defined as:(feed solute conc. - product solute conc.)/feed solute conc.
f) pure water permeation rate, and
g) product rate for each experiment conducted.

CONTINUED

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1984-86	$161,004			$161,004

REPORTS

STATUS AND COMMENT

The contractor has finished the construction of the test epuipment and its modification and is able to perform the experiment at 1000 psig. Some reliable data were obtained using aromatic polyamide membranes supplied by NRC. The project is proceeding more slowly than expected. However, 1the contractor will possibly be able to supply necessary data quickly, once the test facility will be fully completes. 84/12/12

PROJECT DATA SHEET # 385

TITLE Catalysts for Sensitized Solar Production of Hydrogen from Water

CONTRACT # Research Agreement Program

CONTRACTOR University of Waterloo
Faculty of Engineering
Waterloo, Ontario
N2L 3G1

PRINCIPAL INVESTIGATOR K.F. O'Driscoll
Tele.: (519) 885-1211
Ext. 2702

PROGRAM IDENTIFICATION 4.3.7.9
Bioenergy-Strategic Studies/
Biochemical Production of Hydrogen

DURATION April 1983 - March 1984

COST $10,000

SPONSOR Energy Mines & Resources

OBJECTIVE

To prepare and develop efficient polymer entrapped and/or support redox catalysts for light induced hydrogen generation from water.

DESCRIPTION

Continuation of design and development of an interpenetrating polymer network which will be able to accommodate all of the necessary catalytic components in a supported fashion. Results of our studies on the Electro-chemical behavior of Viologen Polymers suggest that, even though the catalytic components are immobilized by binding to the polymer or by entrapment within the polymer, electron mobility from photoactive donor to electron acceptor to metal dispersion is very feasible. In developing such a polymer system, the photoactive donor Ru(bipy)+ will be supported on a polymer functionalized with (bipy) and the electron acceptor will result by attachment of viologen moieties to a polymer functionalized with pyridine units. A dispersion of active metal will be incorporated within the polymer matrix by employing techniques which have previously been developed in our laboratories. Other modifications of donor systems matrices may be explored.

In order to assess the catalytic activity of these photo-redox systems, hydrogen generation studies with respect to time will be carried out. Since we have recently acquired a new gas chromatograph with an automatic gas sampling valve, some attention will be given to the design and construction of a continuous system. This will enable catalyst lifetime studies to be carried out as well as continuous performance data to be acquired.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$10,000			$10,000

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET #	202	**PROGRAM IDENTIFICATION**	4.3.7.10 Bioenergy-Strategic Studies/ Oil-Bearing Microbes
TITLE	Oil-Bearing Microbes: Microbial Systems for Liquid Fuels	**DURATION**	November 1980 - December 1983
CONTRACT #	Strategic Grant	**COST**	$117,705
CONTRACTOR	University of Toronto Dept. of Chemical Engineering Toronto, Ontario M5S 1A4	**SPONSOR**	Natural Sciences and Engineering Research Council
PRINCIPAL INVESTIGATOR	M. Wayman		

OBJECTIVE

This research is concerned with the conversion of atmospheric carbon dioxide to liquid fuels by microbial systems. In these systems photosynthetic microbes, under the action of light convert atmospheric carbon dioxide to carbohydrates and other components of photosynthate. Photosynthate serves as substrate for conversion by other, non-photosynthetic microbes to liquid fuels such as ethanol, butanol or oils.

DESCRIPTION

Bacteria able to generate high concentrations of high energy compounds have been identified, studied and reported; and attention has been concentrated on the photosynthetic generation of substrates for the bacteria to feed on. Carbon dioxide reduction by green algae, particularily Chlorella pyrenoidosa and Chlamydomonas ulvaensis, have been examined. Since both of these require nitrogen for growth, the nitrogen-fixing cyanobacterium Anabaena flos-aquae was also studied, hoping that the mixed cultures would require no exogenous nitrogen addition. The criteria used in the investigations were biomass production and carbohydrate production; and the variables studied included length of photoperiod per day, CO concentration, culture medium pH and composition, particularily N,P,Fe, Mg and trace elements.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1980-81	$35,000			$ 35,000
1981-82	$38,990			$ 73,990
1982-83	$43,715			$117,705

REPORTS

LORA J.H., and WAYMAN M., "Autohydrolysis of Aspen Milled Wood Lignin," Can. J. Chem., 58, (1980).

WAYMAN M., LORA J.H., "Further Studies on Delignification of Wood by Autohydrolysis and Extraction," Tappi, 62 (9), 113-114 (1979).

LORA J.H., and WAYMAN M., "Simulated Autohydrolysis of Aspen Millec Wood Lignin in the Presence of Aromatic Additives: Changes in Molecular Weight Distribution," J. Appl. Polym. Sci. 23, 1973, (1979).

WAYMAN M., and LORA J.H., "Simulated Autohydrolysis of Aspen Milled Wood Lignin in the Presence of Aromatic Additives: Structural Modifications," J. Appl. Polym. Sci. 24, (1980).

WAYMAN M., ROUSSEAU J.D., KORMENDY A.G., "Oil-Bearing Microbes: Microbial Systems for Liquid Fuels," Contractors Meeting, March 30, 1982.

WAYMAN M., JENKINS A.D., and KORMENDY A.G., "Bacterial Production of Fats and Oils," In Microbial Lipids, Pergamon Press, 1983. Ed. Ratledge, C.

CONTINUED

STATUS AND COMMENT

Completed

84/12/01

PROJECT DATA SHEET # 314

TITLE Hydrocarbon Production from Algal and Fungal Biomass

CONTRACT # Strategic Grant

CONTRACTOR
University of Waterloo
Dept. of Biology
Waterloo, Ontario
N2L 3G1

PRINCIPAL INVESTIGATOR C.I. Mayfield

PROGRAM IDENTIFICATION 4.3.7.10 Bioenergy-Strategic Studies/ Oil-Bearing Microbes

DURATION November 1982 - November 1985

COST $143,000

SPONSOR Natural Sciences and Engineering Research Council

OBJECTIVE

To optimize the lipid production of certain microbes and algae and to develop a procedure for extracting this lipid.

DESCRIPTION

Studies on the use of cheap carbohydrate or cellulosic energy sources, either as direct additions to the growth medium or as energy sources for bacterial or fungal growth with consequent CO production, will be carried out. The possibility that nitrogen fixation by Azotobacter sp. using these substrates (or their decomposition products) could provide fixed nitrogen for algal biomass production systems will also be investigated. Nitrogen-fixing Azotobacter cells have a substantial membrane component so as to provide respiratory protection (O removal) for the O sensitive nitrogenase enzyme system, and thus wil serve to enrich the lipid hydrocarbon yield of the biomass system.

Thus the proposed study would investigate algal biomass production and attempt to achieve high lipid contents in the cells. Release of the lipid hydrocarbon equivalents of the biomass following homogenization and treatment with free radicals would be the other main objective of this aspect of the study.

We will attempt to optimize growth rate and lipid (membrane lipid and triglyceride lipid) production in a number of well-known fast-growing fungi (e.g. Chaetomium cellulolyticum, Chrysonilia sitophila)

All membranes are a rich souce of straight chain fatty acids and can be a substantial fraction of the biomass of cells, particularly eukaryotic cells.

Both ozone treatment and direct free-radical treatment with O from KO will be used as a means of releasing the hydrocarbon equivalents of membranes and triglycerides from algal and fungal biomass. These treatments also cause some lipid peroxidation. However, the balance between lipid peroxidation and de-esterification can be controlled by varying the intensity and duration of the free radical treatment. Release of free fatty acids and products of lipid peroxidation from the membrane and triglyceride elements of biomass will be monitored by gas-liquid chromatography.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1982-83 1983-84 1984-85	$ 47,000 $ 48,000 $ 48,000			$ 47,000 $ 95,000 $143,000

REPORTS

CONTINUED

STATUS AND COMMENT

Working in collaboration with W.B. Kendrick and J.E. Thompson, Dept. of Biolcgy.
84/12/07

PROJECT DATA SHEET # 386

TITLE	Plant & Microbial Biomass as Sources of Renewable Hydrocarbons for Synthetic Lubricants and Fuels
CONTRACT #	Research Agreements Program
CONTRACTOR	University of Waterloo Faculty of Engineering Waterloo, Ontario N2L 3G1
PRINCIPAL INVESTIGATOR	J.E. Thompson Tele.: (519) 885-1211 Ext. 3209
PROGRAM IDENTIFICATION	4.3.7.10 Bioenergy-Strategic Studies/ Oil-Bearing Microbes
DURATION	April 1983 - March 1984
COST	$23,000
SPONSOR	Energy Mines & Resources

OBJECTIVE

1) To develop low cost methods for using the membrane lipids of plant and microbial biomass as a source of fatty acids for the formation of synthetic lubricants.
2) To examine the feasibility of using secondary lipid metabolites formed in aging (senescing) plant biomass as additives for conferring specialized properties on lubricants, and to develop low cost methods for producing these metabolites from plant and microbial biomass.
3) To develop low cost methods for converting the hydrocarbon equivalents of membranes in plant and microbial biomass into liquid fuels.

DESCRIPTION

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$23,000			$23,000

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 200

TITLE Continuous Ethanol Production Using Immobilized Cells of Zymomonas mobilis

CONTRACT # Strategic Grant

CONTRACTOR
University of Western Ontario
Faculty of Biochemical Eng.
London, Ontario
N6A 5B9

PRINCIPAL INVESTIGATOR A. Margaritis

PROGRAM IDENTIFICATION 4.3.7.11
Bioenergy Strategic Studies/
Immobilized Cell Techniques for
Fuel Production

DURATION November 1980 - November 1983

COST $85,635

SPONSOR Natural Sciences and Engineering Research Council

OBJECTIVE

A novel approach is proposed where immobilized cells of Zymomonas mobilis are to be used as catalysts for the continuous production of ethanol from carbohydrates. The proposed immobilized cell bioreactor systems have many potential advantages when compared to conventional batch fermentor systems used today for alcohol production.

DESCRIPTION

1. Optimization of Immobilization Methods.
   - a) adsorption or covalent bonding of cells to sand particles
   - b) entrapment of cells in polyacrylamide gel and carrageen polymers
   - c) microencapsulation of cells using different polymeric materials.
2. Bioreactor Development and Optimization.
   The following bioreactor systems will be investigated.
   - a) continuous packed bed column bioreactor
   - b) continuous stirred tank bioreactor with micro screens
   - c) fluidized bed bioreator using cells immobilized on solids with specific gravity between 2 and 3
   - d) ordinary batch and continuous stirred tank bioreactor using freely suspended cells.
3. Experimental Parameters.
   - a) flow rate and glucose concentration of feed
   - b) ethanol concentration
   - c) ethanol yields
   - d) effects of temperature and pH
   - e) half-life of the immobilized cells under different operating conditions
   - f) ethanol productivity per unit bioreactor volume
   - g) maximum glucose and ethanol concentrations which inhibit ethanol production.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1980-81	$27,500			$27,500
1981-82	$30,635			$58,135
1982-83	$27,500			$85,635

CONTINUED

REPORTS

Related publications as of 1980.

MARGARITIS A., ROWE G., and BALTUS T., "Enzymatic Hydrolysis of Rice Hulls," Develop. Ind. Microbiol., Vol. 21, 1980.

MARGARITIS A., and KENNEDY K. "The Application of an Air-Lift Fermenter in the Production of Biosurfactants," Develop. Ind. Microbiol., Vol. 21, 1980.

MARGARITIS A., and CREESE E., "Toxicity of Surfactants in the Aquatic Environment: A Review," in "Waste Treatment and Utilization," editors Moo-Young M., and Farguhar G.J., pp. 445-462, Pergamon Press, Oxford, England, 1980.

MARGARITIS A., ZAJIC J.E., GERSON D.F., "The Production and Surface Active Properties of Microbial Surfactants," Biotech. Bioeng. Vol. 21, No. 7, 1151-1162, 1979.

STATUS AND COMMENT

PROJECT DATA SHEET #	284	**PROGRAM IDENTIFICATION**	4.3.7.11 Bioenergy Fundamental Studies/ Immobilized Cell Techniques for Fuel Production
TITLE	Performance Evaluation of Variable-Surface Area Bioreactors for Cellulose Utilization	**DURATION**	May 1983 - April 1984
CONTRACT #	31926-3-0048(DSX83-00009)	**COST**	$ 45,300
CONTRACTOR	Bioreact Engineering Royal Military College of Canada Kingston, Ontario K7L 2W3	**SPONSOR**	Bioenergy Program National Research Council
PRINCIPAL INVESTIGATOR	P.P. Matteau Tele: (613) 993-1342	**SCIENTIFIC AUTHORITY**	R.P. Overend National Research Council Montreal Road Building R-105, Rm 135 Ottawa, Ontario K1A OR6 Tele: (613) 993-1342

OBJECTIVE

1. To design/construct six equal volume bioreactors - two each of a tubular, a radial flow and tapered bed. Each pair would differ in that the length-to-diameter ratios would differ.
2. To study the performance of these reactors using immobilized whole cells (Saccharomyces cerevisiae or Zymomonas mobilis and Trichoderma viride.
3. To correlate of the data obtained from each of these systems in order to obtain performance curves and scale-up parameters for each reactor configuration.

DESCRIPTION

The contractor has recently studied the use of modified reactor configurations for reactions using high cell densities (immobilized enzymes/whole cells). When high cell densities are used in conventional packed-bed tubular reactors for fermentations involving gas formation (ethanol, butanol, butanediol) some problems are liquid hold-up, channelling of the substrate, and increased pressure drops across the reactor. Solutions to these problems are the use of fixed-film reactors with large and tubular horizontal reactors with in situ gas/liquid separation.

An alternative to these solutions found effective for such heterogeneous reactions is to use reactors whose surface area increases in relation to the direction of flow. Two specific examples which have been successfully demonstrated are the radial-flow packed-bed reactor and the upflow tapered packed-bed reactor.

Through this contract the performance of both of these reactor types will be compared with that of a tubular packed-bed reactor. Use of at least two length-to-diameter ratios at constant reactor volume will permit the critical evaluation of the performance of these reactor configurations. Sufficient data should be available so as to model the systems and allow the estimation of scale-up parameters for each reactor type.

The performance of each reactor is to be evaluated by varying feed rates and substrate concentrations over the ranges expected for commercial operations. The perfomance will be evaluated by analyzing the following variables during continuous reactor operation: inlet and outlet substrate concentration; pressure drop across the reactor; rate of gas production; rate of cell formation.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$ 45,300			$ 45,300

REPORTS

Final Report has been submitted and accepted

CONTINUED

STATUS AND COMMENT

Project is complete

84/11/27

PROJECT DATA SHEET #	349
TITLE	Suspension and Immobilized viable Cell Systems in Butanol-Acetone Fermentation
CONTRACTOR	National Research Council Div. of Biological Sciences Microbiology Group 100 Sussex Drive Ottawa, Ontario
PRINCIPAL INVESTIGATOR	I.A. Veliky
PROGRAM IDENTIFICATION	4.3.7.11 Bioenergy-Strategic Studies/ Immobilized Cell Techniques for Fuel Production
DURATION	April 1982 - March 1985
COST	$237,300
SPONSOR	Division of Biological Sciences Bioenergy Program National Research Council

OBJECTIVE

To study the physiological, biochemical and morphological characteristics of *Clostridium acetobutylicum* strains as free and immobilized systems in butanol-acetone fermentation.

DESCRIPTION

1. To study the basic macro- and micro-nutrient requirements of *Clostridium* strains, develop a synthetic fully defined medium and optimize the conditions on acetone-butanol production.
2. To study the effect of butanol (solvent) toxicity to the *Clostridium* strains.
3. To study immobilization techniques of whole active (viable) cells of Clostridium strains by entrappment in alginate gel and/or attachment to porous readily available materials and evaluate the production of butanol, acetone and ethanol under those conditions.
4. To study the effect of enzymatic preparations (e.g. cellobiase, amylases, invertase, lactase etc.) on solvent production rates by *Clostridium* grown on various carbon sources.

FUNDING

FISCAL YEAR	SPONSOR	BIOLOGICAL SCIENCES		CUMULATIVE TOTAL
1982-83	$ 35,000	$50,000		$ 85,000
1983-84	$ 66,000	$ 8,800		$159,800
1984-85	$ 68,500	$ 9,000		$237,300

REPORTS

VIDOLI R., YAMAZAKI H., NASIM A., VELIKY I.A., "A Novel Procedure for the Recovery of Hybrid Products from Protoplast Fusion," Biotechnology Letters, Vol. 4 (12), pp 781-784, 1982.

WILLIAMS R.E. and VELIKY I.A., "Alcohol Production by Microorganisms Immobilized in Metal Ion Gelled Polysaccharides," Proc. of the Fourth Miami International Conference on Alternative Energy Sources, Ed. T. Nejat Veziroglu, 1982.

WILLIAMS R.E. and VELIKY I.A., "The Use of Immobilized Cells in Fermentations," Proceedings of the Fourth Bioenergy R&D Seminar, pp. 481-484, Winnipeg, Manitoba, 1982.

WELSH F.W. and VELIKY I.A., "Production of Acetone-Butanol from Acid Whey," Biotechnology Letters, 6(1), 61-64, 1984.

TANAKA H., MATSUURA M. and VELIKY I.A., "Diffusion Characteristics of Substrates in Ca-alginate Gel Beads," Biotechnology and Bioengineering, 26, 53-58, 1984.

STATUS AND COMMENT

PROJECT DATA SHEET #	391	**PROGRAM IDENTIFICATION**	4.3.7.11 Bioenergy-Strategic Studies/ Immobilized Cell Techniques for Fuel Production
TITLE	Development of Novel Fluidized Bioreactor Systems		
CONTRACT #	31155-2-6407 (OSU82-00006)	**DURATION**	April 1982 - March 1984
CONTRACTOR	University of Western Ontario Stevenson-Lawson Building Room 101 London, Ontario N6A 5E8	**COST**	$151,348
		SPONSOR	Plant Biotechnology Institute National Research Council
PRINCIPAL INVESTIGATOR	A. Margaritis	**SCIENTIFIC AUTHORITY**	W. Kurz Plant Biotechnology Institute National Research Council Canada Saskatoon, Saskatchewan S7N 0W9

OBJECTIVE

The basic overall objective is to develop novel bioreactor systems which are based on the principle of fluidization involving any combination of the solid, liquid, and gas phases.

DESCRIPTION

the first year of the proposed contract research will be devoted to the study of basic fundamental phenomena of mass transfer and hydrodynamic characteristics of the fluidized bioreactor. The second year will be spent on the application of the fluidized bioreactor system(s) to various fermentation systems using immobilized cells. The cells will be immobilized on solid carriers such as sand and also entrapped in different polysaccharide matrices.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1982-83	$ 70,634			$ 70,634
1983-84	$ 80,714			$151,348

REPORTS

Final Report received

STATUS AND COMMENT

Contract concluded

PROJECT DATA SHEET #	277
TITLE	Solid-State Fermentation of Poplar Wood
CONTRACT #	31155-2-2844
CONTRACTOR	Queen's University Dept. of Chemical Engineering Kingston, Ontario K1G 3Z5
PRINCIPAL INVESTIGATOR	D.H. Bone

PROGRAM IDENTIFICATION	4.3.7.12 Bioenergy Strategic Studies/ Cellulase
DURATION	December 1982 - December 1983
COST	$46,302
SPONSOR	Bioenergy Program National Research Council (Liquid Fuels Task)
SCIENTIFIC AUTHORITY	L. van den Berg Biological Sciences National Research Council Ottawa, Ontario K1A 0R6 Tele.: (613) 992-3310

OBJECTIVE

To examine six filamentous fungi for their ability to produce cellulolytic enzymes when growing on poplar wood in solid-state fermenters and to identify the optimal environmental conditions for cellulase production.

DESCRIPTION

The following factors will then be studied in detail:

1. Type of fungi: six widely different types will be selected, including Trichoderma reesei, CRM-9414 and E-581.
2. Ratios of weight of wood substrate to volume of nutrient solution.
3. Temperature
4. Wood pre-treatment: steam exploded wood will be compared with wood shavings.

Initially, tests will be made to determine the best way of preparing and applying inoculum, satisfactory nutrient requirements and the required buffering capacity for pH control.

Experiments will be conducted using 500 ml jars as growth chambers partially filled with alkali-treated poplar wood shavings.

Enzyme production will be related to soluble protein content to estimate changes in specific cellulolytic activities. Dry weight loss and solubilities will yield information on the extent of cellulose degradation and rates of growth of fungi.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1982-83	$14,000			$14,000
1983-84	$32,302			$46,302

REPORTS

Final report not completed.

STATUS AND COMMENT

Results of this completed study indicated that production of enzymes under the best conditions was slow.

PROJECT DATA SHEET #	337	**PROGRAM IDENTIFICATION**	4.3.7.12 Bioenergy-Strategic Studies/ Cellulase
TITLE	Regulation of Cellulase Production in Industrially Important Microorganisms	**DURATION**	November 1982 - November 1984
CONTRACT #	Strategic Grant	**COST**	$54,800
CONTRACTOR	University of Ottawa Dept. of Biology Ottawa, Ontario K1n 6N5	**SPONSOR**	Natural Sciences and Engineering Research Council
PRINCIPAL INVESTIGATOR	D.J. Kushner		

OBJECTIVE

The production of cellulolytic enzymes will be studied in a number of bacteria and fungi, with special attention to the mechanisms by which the synthesis of these enzymes are regulated, including induction by cellulose and other substrates, and repression by glucose and other end products. Attempts will be made to obtain strains that produce more cellulases, and/or those in which the synthesis of these enzymes is less subject to repression by end products. Activity of the strains studied will be tested first on purified celluloses, then on different wood products. The possibility that the organisms studied contain substantial amounts of cellulases in cell-bound forms will be studied.

DESCRIPTION

The work proposed is to be carried out in collaboration with Dr. J. Saddler of FORINTEK Canada Corp., Ottawa.

1. Selection of microorganisms will include: *Trichoderma* sp. because of their high cellulolytic ability. *Cellvibrio gilvus*, as a model bacterium, which has already been studied and which would serve as a good organism to investigate selection of more cellulolytic or deregulated mutants. Other microorganisms, such as *Cellulomonas* and the anaerobe *Clostridium thermocellum* will also be studied.
2. With the microorganisms chosen, experiments will be carried out to determine whether cellulose and its different forms and derivatives (crystalline and amorphous cellulose; CMC) induce formation of enzymes of the cellulase complex, and if contact between the cell and the insoluble substrates is necessary for this induction. It will also be determined if glucose and cellobiose repress formation of the above enzymes.
3. With the microorganisms tested, especially those that produce high levels of cellulases, the possibility will be examined that cellulose stimulates growth, even in a rich complex medium, as has been found for *C. gilvus* and if, under these conditions, the addition of glucose inhibits growth. It is likely that any mutants which are no longer repressed by the end products of glucose digestion might grow faster in a system containing cellulose fibres and might come to dominate the population.
   Experiments will at first be carried out in batch cultures, then in continuous cultures.
4. If more active, or less repressible mutants are found and prove to be stable, further experiments will be performed using different cellulose compounds and wood products, with the aim of attaining a commercially acceptable microbial degradation of cellulose. Among the substrates to be tested in this work are: Commercial cellulose such as Avicel, Whatman Cf cellulose, CMC and pretreated wood and agricultural residues such as steam exploded aspen, solvent extracted aspen and a variety of pretreated agricultural residues.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1982-83 1983-84	$28,300 $26,500			$28,300 $54,800

CONTINUED

REPORTS

VLADUT-TALOR M., KAURI T. and KUSHNER D.J., "Nutritional control of growth and cellulose Degradation by a Cellulomonas species", Presented as a poster (AM6p) at the 1984 Canadian Society of Microbiologists meeting, Kingston, Ontario.

STATUS AND COMMENT

Dr. Saddler will supply most of the microorganisms to be used. Also the first experiments on anaerobic cellulose digesters will be done at FORINTEK. D.J.K. 84/11/29

PROJECT DATA SHEET # 341		**PROGRAM IDENTIFICATION**	4.3.7.12 Bioenergy-Strategic Studies/ Cellulase
TITLE	Aerobic Production of Fuels, Chemicals, Cellulolytic Enzymes and Sugars from Wood Cellulose	**DURATION**	April 1981 - March 1985
CONTRACTOR	National Research Council Division of Biological Sciences 100 Sussex Drive Ottawa, Ontario K1A 0R6	**COST**	$388,000
		SPONSOR	Division of Biological Sciences Bioenergy Program National Research Council
PRINCIPAL INVESTIGATOR	S.J.B. Duff, A.W. Khan, W.M.L. Morisset, W.D. Murray M.F. Podruzny, L. van den Berg		

OBJECTIVE

To develop a fermentation system for the economical large scale production of cellulolytic enzymes by *Trichoderma* spp. preferably using wood as a substrate.

DESCRIPTION

The work includes: (a) study of factors limiting cellulase production in submerged cultures (agitation, aeration, etc.) and in solid state cultures; (b) study and development of techniques to obviate contamination and mutation problems in large scale reactors without resorting to stringent aseptic and sterile techniques; (c) development of reactors optimizing conditions for enzyme production and cellulose hydrolysis.

FUNDING

FISCAL YEAR	SPONSOR	BIOLOGICAL SCIENCES		CUMULATIVE TOTAL
1982-83	$ 75,000			$ 75,000
1983-84	$180,000			$255,000
1984-85	$ 40,000	$93,000		$388,000

REPORTS

MORISSET W.M.L., and KHAN A.W., "Relation Between Filter Paper Activity and Saccharifying Ability of a *Trichoderma* Cellulase System," Biotechnol. Lett.,6: 375-378, 1984.

MURRAY W.D., and DUFF S.J.B., "Studies on the Production and Use of Cellulases for the Conversion of Cellulose to Fermentable Sugars and Alcohol," Proceedings IV Int. Symp. on Alcohol Fuels Technol., Vol 2: 179-183, 1984.

STATUS AND COMMENT

Addition of some chemicals has been found to increase cellulase production in submerged cultures; the relationship between filter paper activity and hydrolytic potential of enzyme solutions has been clarified; progress is being made in the development of a non-aseptic process for hydrolysis of cellulose. 84/12/06

1982-84: Funding from both sources under "SPONSOR"

PROJECT DATA SHEET # 346

TITLE Process Development for Enzymatic Hydrolysis of Cellulose

CONTRACT # 31926-3-0047(OSX83-0053

CONTRACTOR
Université du Québec
Institut Armand-Frappier
531, boul. des Prairies
Case postale 100
Laval, Québec
H7N 4Z3

PRINCIPAL INVESTIGATOR D.S. Chahal

PROGRAM IDENTIFICATION 4.3.7.12
Bioenergy-Strategic Studies/
Cellulase

DURATION April 1983 - March 1985

COST $87,308

SPONSOR
Bioenergy Program
National Research Council
(Liquid Fuels Task)

SCIENTIFIC AUTHORITY
W. Khan
National Research Council
Sussex Drive
Ottawa, Ontario
K1A 0R6
Tel.: (613) 993-1342

OBJECTIVE

To develop an enzyme production process characterized by high cellulase activity per unit volume (10 FP units/ml) and high productivity per unit time.

DESCRIPTION

The contractor will study the effect of increasing the concentration of cellulose, in combination with other factors, on the concentration of the enzyme cellulase and its rate of production of Trichoderma reesei. This will consist of a comparison of enzyme production from wood cellulose and commercial cellulose at concentrations of cellulose ranging from 5% to 25% in conventional and solid state fermentors.
Phase I Selection of the most suitable mutant, wood substrate, pretreatment and medium.
Phase II A study of the effect of cellulose concentrations varying from 5% to 25% in a conventional fermentor, flasks, and solid state fermentors. Concurrent study of the effect of hemicellulose and lignin concentration on enzyme production.
Phase III A study of the hydrolysis of cellulose to determine the extent of hydrolysis at high concentrations of wood cellulose in a system with high cellulase per unit volume.
Phase IV Comparison of 1-step and 2-step process from cellulose to ethanol.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1983-84 1984-85	$ 52,308 $ 35,000			$ 52,308 $ 87,308

REPORTS

CHAHAL D.S., "A New Approach to Produce Cellulase complex with Trichoderma reesei on Lignocelluloses for Ethanol (Fuel) Production," Proc. 6th International Symposium on alcohol Fuels Technology, Ottawa, Canada, Vol. 2, p 121-127, May 21-25, 1984.

STATUS AND COMMENT

Initial results on enzyme production and concentration were very promising.
84/11/29

PROJECT DATA SHEET #	348	**PROGRAM IDENTIFICATION**	4.3.7.12 Bioenergy-Strategic Studies/ Cellulase
TITLE	Bioconversion of Lignocellulosics by Streptomyces flavogriseus	**DURATION**	April 1982 - March 1984
CONTRACTOR	National Research Council Div. of Biological Sciences Microbiology Group 100 Sussex Drive Ottawa, Ontario	**COST**	$177,400
		SPONSOR	Division of Biological Sciences Bioenergy Program National Research Council
PRINCIPAL INVESTIGATOR	K. Johnson C.R. MacKenzie		

OBJECTIVE

1) create biotechnological systems for the enzymic saccharification of lignocellulosics, and
2) to conduct fundamental studies directed towards an understanding of the molecular mechanisms of enzymic cellulose and xylan hydrolysis in bacterial systems.

DESCRIPTION

An intensive physiological and enzymic study which addresses the common first-step of processes designed for biological conversion of lignocellulosics to fuels and chemical feedstocks: the conversion of cellulose and xylans to fermentable sugars. The over-all objectives of this programme are to:

1. Determine optimum growth conditions for production of cellulase and xylanase activities and investigate the optimization of glucose isomerase.
2. Isolate, purify and characterize the cellulases.
3. Isolate, purify and characterize the xylanases.

FUNDING

FISCAL YEAR	SPONSOR	BIOLOGICAL SCIENCES		CUMULATIVE TOTAL
1982-83	$39,400	$30,000		$ 69,400
1983-84	$93,000	$15,000		$177,400

REPORTS

MACKENZIE C.R., BILOUS D. and JOHNSON K.G., "Streptomyces flavogriseus Cellulase: Evaluation under Various Hydrolysis Conditions," Biotechnology and Bioengineering, XXVI 590-594, 1984.

MACKENZIE C.R., BILOUS D. and JOHNSON K.G., "Purification and Characterization of an Exoglucanase from Streptomyces flavogriseus, Can. J. Microbiol. (In press), 1984).

STATUS AND COMMENT

1. Have obtained optimum growth conditions for production of cellulase and xylanase activities.
2. Several extracellular cellulases have been separated of which 4 display endoglucanase activity while the fifth is an exoglucanase which has been purified to molecular homogeneity and characterized.
3. Acid swollen cellulose was extensively hydrolysed at concentrations up to 10% while crystalline cellulose was more resistant.
4. Four distinct xylanases have been isolated. Two of these are anionic proteins which have been purified to molecular homogeneity and characterized. One of the two remaining cationic species has been purified and similarly characterized.
5. The anionic and cationic xylanase species act synergistically in the hydrolysis of xylan.
6. A xylose isomerase from S. flavogriseus has been purified to homogeneity and characterized

84/12/06

PROJECT DATA SHEET # 372

TITLE A Mass Transfer/Interfacial Study of Cellulase Activity

CONTRACT # 31926-3-5027 (OXT83-00214)

CONTRACTOR
McGill University
Dawson Hall, Room 408
853 Sherbrooke Street West
Montreal, Québec
H3A 2T6

PRINCIPAL INVESTIGATOR R.J. Neufeld

PROGRAM IDENTIFICATION 4.3.7.12
Bioenergy-Strategic Studies/Cellulase

DURATION November 1983 - March 1987

COST $112,870

SPONSOR
Bioenergy Program
National Research Council

SCIENTIFIC AUTHORITY
S. Hasnain
Division of Energy
National Research Council
Building R-105, Room 138
Ottawa, Ontario
K1A 0R6
Tele.: (613) 993-1342

OBJECTIVE

1) Development of a mass transfer model for cellulase activity.
2) Characterize interfacial properties of reaction system.
3) Modify interfacial properties of reaction system to enhance enzyme activity.
4) Determine effects of shear on cellulase enzymes.
5) Develop physico-chemical mechanistic model.

DESCRIPTION

The project is to be carried out in phases:

Phase I: Literature search, establishment of goals and objectives and research methodology and some preliminary investigations. At the end of this phase an interim report will be submitted to the Scientific Authority with the proposed research plan for Phase II

Phase II: With the approval of the research plan by the Scientific authority, the program of research will be initiated. At the end of this phase the Principal Investigator will submit a report on the years's activities along with a proposed research plan for Phase III

Phase III: The acceptance of the Phase III workplan by the Scientific Authority will commence the final phase of the project. A report of the year's activities will be sibmitted to the Scientific Authority by March 31, 1986, and a draft final and final report will be submitted on the complete project upon completion.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1983-84	$ 6,939			$ 6,939
1984-85	$ 47,461			$ 54,400
1985-86	$ 33,000			$ 87,400
1986-87	$ 25,470			$112,870

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 373

TITLE Process Development for Enzymatic Hydrolysis of Cellulose

CONTRACT # 31926-3-0047 (OSX83-00053)

CONTRACTOR
Université du Québec
Institut Armand-Frappier
531 Boul. des Prairies
C.P. 100
Succ. Laval-des-Rapides
Laval, Québec
H7N 4Z3

PROGRAM IDENTIFICATION 4.3.7.12
Bioenergy-Strategic Studies/ Cellulase

DURATION July 1983 - July 1984

COST $87,308

SPONSOR
Bioenergy Program
National Research Council

SCIENTIFIC AUTHORITY
W. Khan
National Research Council
Division of Biological Science
Rideau Falls Lab
Ottawa, Ontario
K1A 0R6
Tele.: (613) (992-3843)

OBJECTIVE

To develop an enzyme production process characterized by high cellulase activity per unit volume and high productivity per unit time.

DESCRIPTION

The contractor will study the effect of increasing the concentration of cellulose, in combination with other factors, on concentration of the enzyme cellulase and its rate of production by *Trichoderma reesei*. This will consist of a comparison of enzyme production from wood cellulose and commercial cellulose at concentrations of cellulose ranging from 5% to 25% in conventional and solid state fermentors.
Phase I Selection of the most suitable mutant, wood substrate, pretreatment and medium.
Phase II A study of the effect of cellulose concentrations varying from 5% to 25% in a conventional fermentor, flasks, and solid state fermentors. Concurrent study of the effect of hemicellulose and lignin concentration on enzyme production.
Phase III A study of the hydrolysis of cellulose to determine the extent of hydrolysis at high concentrations of wood cellulose is a system with high cellulase per unit volume.
Phase IV Comparison of 1-step and 2-step process from cellulose to ethanol.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$87,308			$87,308

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 398

TITLE
Morphological Evaluation of Cellulolytic Fungi and Pretreated Lignocellulosic Materials

CONTRACT #
31926-3-5038 (0SX83-00205)

CONTRACTOR
Forintek Canada Corp.
Eastern Laboratory
800 Montreal Road
Ottawa, Ontario
K1G 3Z5

PRINCIPAL INVESTIGATOR
J.N. Saddler

PROGRAM IDENTIFICATION
4.3.7.12
Bioenergy-Strategic Studies/Cellulase

DURATION
January 1984 - March 1984

COST
$15,000

SPONSOR
Bioenergy Program
National Research Council

SCIENTIFIC AUTHORITY
S. Hasnain
National Research Council
Division of Energy
Building R-105, Room 138
Ottawa, Ontario
K1A 0R6
Tele.: (613) 993-1342

OBJECTIVE

To undertake morphological (scanning electron microscopy) analyses of natural and genetically engineered cellulolytic fungi grown on cellulosic substrates for a better understanding of substrate adaptation.
To undertake SEM analyses of pretreated lignocellulosic substrates as an aid to the improvement of pretreatment methods for the conversion of wood to fuels and chemicals.

DESCRIPTION

Samples of the microorganism Schizophyllum commune provided by the National Research Council are to be prepared for SEM analyses by the contractor. The contractor will study the samples by SEM, make an assessment of the morphological structures and take the appropriate photographs of relevant structures for later indepth evaluations. Approximately 10 separate samples of the organism are to be examined.
The same conditions apply to the pretreated lignocellulosic material except that about forty samples are to be examined and recorded.
The contractor will prepare brief analyses of the photographed material and present them in two reports (one for the microorganism and the other on pretreatment) along with detailed information on the conditions used in the preparation and examination of all samples.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$15,000			$15,000

REPORTS

Final Report available.

STATUS AND COMMENT

PROJECT DATA SHEET # 468

TITLE Cellulase Production Using Advanced Mutants of *T. reesei*

CONTRACT # E2108 EL27

CONTRACTOR
Iotech Corp. Ltd.
400 Hunt Club Road
Gloucester, Ontario
K1G 2N3

PRINCIPAL INVESTIGATOR B. Foody

PROGRAM IDENTIFICATION 4.3.7.12
Bioenergy-Strategic Studies/ Cellulase

DURATION April 1983 - December 1985

COST $83,000

SPONSOR Agriculture Canada

SCIENTIFIC AUTHORITY
E. Manolakis
Engeering & Statistical Research Branch
Agriculture Canada
Engeering Bldg #94
C.E. Farm
Ottawa, Ontario
K1A OC6
Tele.: (613) 995-9671

OBJECTIVE

To determine optimum fermentation process conditions for the production of cellulose enzyme activity by the mold *T. reesei* P-37. To use steam exploded corn stover and wheat straw as fermentation substrate.

DESCRIPTION

1. Pilot scale steam explosion of corn stover and wheat straw at three different cooking conditions.
2. Lignin and hemicellulose extractions using a variety of methods including water and caustic.
3. Shake flask fermentations of P-37 on the substrate from Task 1, and assay enzyme activities.
4. Choosing the most desirable substrates, optimize enzyme fermentation through media modifications.
5. Study the effect of inhibitors in the substrate.
6. Carry out 28 L fed batch enzyme fermentations at least 10% substrate conc'n.
7. Compare efficiency of enzyme in Task 6 with other sources s.a. C-30 and commercial preparations.
8. Produce a concentrated hydrolysate using enzyme from Task 6.
9. Carry out 28 L fed batch ethanol fermentations using hydrolysate in Task 8 (S.A. to clarify this item as stated in the proposal.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1983-84 1984-85	$37,000 $46,000			$37,000 $83,000

REPORTS

STATUS AND COMMENT

SOCIO-ECONOMIC-TECHNICAL STUDIES

Social Infrastructure

Technology Assessment

Economic Assessment

Information

Legal Studies

PROJECT DATA SHEET # 177

TITLE
Sacrificial Agents for
Enhanced Oil Recovery from
Forest Products

CONTRACT #
KL229-1-4117 (OSS81-0047)
C-191

CONTRACTOR
B.C. Research
3650 Wesbrook Mall
Vancouver, B.C. V6S 2L2

PRINCIPAL INVESTIGATOR
J. Howard
Tel.: (604) 224-4331

PROGRAM IDENTIFICATION
4.3.8.2
Socio-Economic-Technical
Studies/Technology Assessment

DURATION
April 1981-March 1984

COST
$194,450

SPONSOR
Energy, Mines & Resources

SCIENTIFIC AUTHORITY
A.J. Dolenko
Conservation & Renewable
Energy, Mines and Resources
460 O'Connor Street
Ottawa, Ontario
K1A 0E4
Tele.: (613) 995-9447

OBJECTIVE

To evaluate suitable silvichemicals and their appropriate derivatives as sacrificial agents for use in tertiary oil recovery systems.
To approach oil companies actively developing surfactant dependent enhanced oil recovery processes for further evaluation of these sacrificial agents (especially in the field).
To approach chemical marketing companies with a vested interest in marketing effective sacrificial agents to promote further sale of their surfactants.

DESCRIPTION

Isolation of Sacrificial Agents

The following byproducts of the forest products industry are thought to have potential as starting materials for sacrificial agent manufacture:

- Kraft black liquor lignin and carbohydrate components.
- Spent sulphite liquor (red liquor) lignin and carbohydrate components.
- "E"-stage liquor from both Kraft and sulphite pulp bleaching stages.
- Prehydrolysis liquor from pretreatment of both chips for pulping and sawdust for conversion into hardboard (Masonite).

The evaluation procedure will take the following form. Well defined montmorillonites will be exposed to solutions of the potential silvichemical sacrificial agents. The adsorption of these agents on the clays can be followed by ultra-violet adsorption spectroscopy where suitable chromophores are present or chemically by total organic carbon analysis. The treated clay will then be exposed to solutions of de-oiled petroleum sulfonates of differing equivalent weights covering the range normally used in oil recovery.

Adsorption of surfactant will be monitored by sulfonate analysis. Comparison of surfactant adsorption with and without pretreatment with silvichemical derivatives will be carried out to identify particular derivatives having potential as sacrificial agent and to ascertain general correlations between the ability of a derivative to function as a sacrificial agent and its physical characteristics (charge, hydrophilic/lipophilic balance, etc.).

Initially experiments will be carried out in sodium chloride solution using sodium montmorillonite. Later the performance of selected sacrificial agents will be evaluated on calcium montmorillonite which has the potential to act as a source of Ca+ ions capable of precipitating the petroleum sulfonates. A sacrificial agent should have the ability to not only coat the clay surfaces to prevent sulfonate adsorption but to contain the Ca+ ions within the clay structure.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1981-82 1982-83 1983-84	$87,450 $65,300 $41,700			$ 87,450 $152,750 $194,450

CONTINUED

REPORTS

STATUS AND COMMENT

The results look promising and a patent application is being filed. Bionergy Program - 84/12/04

PROJECT DATA SHEET # 178

TITLE Technical Assessment of Downdraft Gasifiers

CONTRACT # KL229-1-4118 (0SS81-00022)
C-197

CONTRACTOR Queen's University
Dept. of Chemical Engineering
Kingston, Ontario, K7L 3N6

PRINCIPAL INVESTIGATOR D.W. Bacon
Tel.: (613) 547-3202

PROGRAM IDENTIFICATION 4.3.8.2
Socio-Economic-Technical Studies/Technology Assessement

DURATION April 1981 - May 1983

COST $180,057

SPONSOR Energy, Mines and Resources

SCIENTIFIC AUTHORITY R.P. Overend
National Research Council Canada
Building R-105, Rm 135
Montreal Road
Ottawa, Ontario
K1A 0R6
Tele.: (613) 993-1342

OBJECTIVE

To develop and test quantitative methods to assess the operation and design of down-draft gasifiers

DESCRIPTION

1. Mechanistic and empirical models of down-draft wood gasifiers;
2. Computer simulation programs incorporating these models;
3. Experimental design and data analysis procedures to obtain data and extract information efficiently for assessing and improving the operation of down-draft wood gasifiers;
4. Procedures for establishing limits on the reliability and acceptability of data from gasifier operation.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1981-82	$86,380			$ 86,380
1982-83	$90,689			$177,069
1983-84	$ 2,988			$180,057

REPORTS

Final report published

STATUS AND COMMENT

Working in collaboration with J. Downie and C.C. Hsu.

R.P.O. 84/11/26

PROJECT DATA SHEET # 268

TITLE Update on Wood Liquefaction Technology

CONTRACT # 31155-2-2845 (OSX82-00110)

CONTRACTOR SNC Inc.
1, Complexe Desjardins
P.O. Box 10
Desjardins Postal Station
Montréal, Québec
H5B 1C8

PRINCIPAL INVESTIGATOR J.M. Moffatt
J.C. Dhawan

PROGRAM IDENTIFICATION 4.3.8.2
Socio-Economic-Technical Studies/
Technology Assessment

DURATION October 1982 - January 1983

COST $29,837

SPONSOR Bioenergy Program
National Research Council

SCIENTIFIC AUTHORITY R.P. Overend
National Research Council
Building R-105, Rm 135
Ottawa, Ontario
K1A OR6
Tele.: (613) 993-1342

OBJECTIVE

1. To ascertain the current status and recent progress of each known leading research group.
2. To establish an up-to-date state-of-the-art conceptual process design using the data base developed for ENFOR C-69 and evaluate changes in feasibility and economics.
3. To examine the costs and implications of meeting the hydrogen requirements of such processes.

DESCRIPTION

The current work of the groups who participated in the 'Specialists Meeting in Biomass Liquefaction' held at Saskatoon, Canada, on February 16 & 17, 1982 (Published by the U of Saskatchewan) was updated on the basis of telex questions and phone & visit responses.
The University of Toronto rapid pyrolysis process (Data sheet 325) was used as a design basis for the development of a conceptual flow sheet costed by means of inflation factors on the data used in ENFOR C-69.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1982-83	$29,837			$29,837

REPORTS

MOFFATT J.M., DHAWAN J.C., The SNC Group, "Update on Wood Liquefaction Technology," Montreal, Québec, January 31, 1983. (Available on Microfiche from CISTI)

STATUS AND COMMENT

The report showed that the R&D on wood liquefaction since C-69 had resulted in about a 30% increase in liquid yield and 30% less plant capital investment. If chemicals such as phenol and acetic acid are marketed as co-products the fuel oil produced would be competetively priced against the international oil price for when the wood feedstock is at $20/ODt.

84/12/07

PROJECT DATA SHEET # 312		**PROGRAM IDENTIFICATION**	4.3.8.2 Socio-Economic-Technical Studies/ Technology Assessment
TITLE	Evaluation of an Anaerobic Digester		
CONTRACT #	01843-1-ER19 (OSZ81-00143)	**DURATION**	March 1982 - February 1984
CONTRACTOR	Urgel Delisle et Associé B.P. 60 426 chemin des Patriotes St. Charles sur Richelieu Québec (Québec) JOH 2G0	**COST**	$97.100
		SPONSOR	Agriculture Canada
		SCIENTIFIC AUTHORITY	Roger Chagnon Agriculture Canada Research Station 430 boul. Gouin P.O. Box 457 Saint-Jean, Québec J3B 6Z8 Tel.: (514) 346-4494
PRINCIPAL INVESTIGATOR	M. Cournoyer		

OBJECTIVE

To evaluate for a full year the only full scale, Canadian, plug-flow digester on a dairy farm. The anaerobic digester, which produces biogas from the manure of 350 dairy cows, is used to produce electricity for the farm's needs. A technical and economic analysis of the system was done.

DESCRIPTION

1. Evaluate certain parameters which can be used to identify and control the health of the digester.
2. Evaluate the actual production of the digester, the quality of the biogas and the stability of operation at 35C.
3. To examine the use of biogas for electrical generation.
4. To evaluate the effectiveness of the system for heat recovery.
5. To evaluate a synthetic material for methane storage.
6. To evaluate equipment for stripping water and hydrogen sulfide from the biogas.
7. To study the constraints imposed by the digester on the operations of the farm.
8. To evaluate the systems profitability.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1982-83 1983-84	$55,000 $42,100			$55,000 $97,100

REPORTS

Final report entitled "valuation d'un digesteur anarobie" was issued and can be obtained from CISTI

STATUS AND COMMENT

This anaerobic digester was easily integrated within the normal farm's operation. However, the pay-back period is very long, due to high digester cost.

84/11/29

PROJECT DATA SHEET # 313

TITLE Comparison of Enzymatic & Acid Hydrolysis & Fermentation Methods of Steam Treated Lignocellulosic Agri. Residues

CONTRACT # 01843-1-EL11 (OSZ81-000151)

CONTRACTOR
Forintek Canada Corp
Eastern Laboratory
800 Montreal Road
Ottawa, Ontario
K1G 3Z5

PRINCIPAL INVESTIGATOR J.N. Saddler

PROGRAM IDENTIFICATION 4.3.8.2 Socio-Economic-Technical Studies/ Technology Assessment

DURATION March 1982 - March 1984

COST $430,000

SPONSOR Agriculture Canada (Liquid Fuels Task)

SCIENTIFIC AUTHORITY
E. Manolakis
Engineering and Statistical Research Institute
Research Branch
Agriculture Canada
Ottawa, Ontario K1A 0C6
Tel.: (613) 995-9671

OBJECTIVE

1. To obtain separate product streams of lignin, cellulose and hemi-cellulose and their composite sugars from agricultural residues through the use of steam, acid, and enzymes.
2. To ferment sugars derived from cellulose and hemicellulose through a variety of methods.
3. Perform an economical & technical analysis of the methods with respect to the end products.

DESCRIPTION

1. Using steam explosion with and without acid, and various extraction techniques, obtain separate product streams of lignin, hemicellulose and cellulose and of their derived sugars. Feedstocks include barley straw, wheat straw, corn stover and others.
2. Hemicellulose and cellulose will be hydrolysed by different chemical and enzymatic methods such as: acid, cellulase enzyme systems, and immobilized cell reactors.
3. The contractor will investigate and optimize the fermentation of sugars in batch (or continuous) and immobilized cell reactors using Zymomonas mobilis.
4. The contractor will optimize the fermentation of all sugar streams including mixtures of hexose and pentose streams to solvents by utilizing single or mixed cultures of Clostridium acetobutylicum and C. butylicum (acetone, butanol).
5. The contractor will attempt to induce hemicellulase activity in K. pneumoniae and Clostridium sp. If this is successful, the contractor will investigate the direct hydrolysis/fermentation of hemicellulose by these organisms.
6. The contractor will investigate the simultaneous saccharification and fermentation of hemicellulose, cellulose, and hemicellulose/cellulose mixtures using a combination of various enzyme systems and organisms such as Zymomonas, Saccharomyces, Clostridium and Klebsiella.
7. The contractor will investigate mixed culture fermentation and hydrolysis/fermentation of hemicellulose, cellulose and mixtures thereof for the production C. thermosaccharolyticum of ethanol by Clostridium thermocellum in co-culture with or C. thermohydrosulfuricum.
8. The contractor will perform detailed studies on continuous cultivation and solvent production on some of the promising systems investigated above.
9. The contractor will initiate studies to determine if an immobilized cell (gel beads of fixed film) reactor can be practically devised to accommodate both cellulolytic organisms and ethanol or power solvent producers.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1981-82	$ 10,569			$ 10,569
1982-83	$199,486			$210,055
1983-84	$220,000			$430,000

CONTINUED

REPORTS
STATUS AND COMMENT

PROJECT DATA SHEET # 322

TITLE Technical/Economic Study of Farm and Industrial Scale Fuel Ethanol Plant Employing Vapour Compression Distillation

CONTRACT # 01843-2-EL16 (0SZ82-00044)

CONTRACTOR
Acres Consulting Services Ltd
480 University Avenue
Toronto, Ontario
M5G 1V2

PROGRAM IDENTIFICATION 4.3.8.2 Socio-Economic-Technical Studies/ Technology Assessment

DURATION June 1982 - June 1983

COST $94,350

SPONSOR Agriculture Canada (Liquid Fuels Task)

SCIENTIFIC AUTHORITY
E. Manolakis
Engineering & Statistical
Research Institute
Research Branch
Agriculture Canada
Ottawa, Ontario K1A 0C6
Tel.: (613) 995-9671

OBJECTIVE

To develop designs, cost estimates & performance estimates for biomass to fuel grade ethanol plants using vapour compression distillation methods as opposed to steam distillation systems.

DESCRIPTION

1. To review available base case plant designs from two US DOE reports and other information available of typical, conventional distillation, grain to ethanol conversion plants at production capacities of approximately 1,000,000 L/y and 45,000,000 L/y respectively.
2. To determine mass and energy balances for the base cases for unit operations and the plants in total, and prepare mass and energy flow diagrams.
3. To derive base case capital cost estimates for the two conventional base case plants and their component operations.
4. To estimate ethanol production costs from base case plant designs to determine sensitivity of production cost to: fuel and power costs, feedstock cost, plant capacity factors, cost of capital and discount rate, and DDGS value.
5. To prepare estimates of capital, operating and total ethanol production costs for plants with different capacities.
6. To prepare detailed engineering designs, drawings, energy and mass blance and operating conditions for the vapour recompression distillation systems suitable for distillation to azeotropic ethanol (and anhydrous ethanol, if appropriate) for the large base case plant.
7. To integrate the vapour compression systems into the two base case processes, making all necessary or desirable modifications to the base case configurations. Determine mass and energy balances and flow diagrams for the two base case plants with vapour compression as described in 2 above.
8. To derive base case capital cost estimates of the two base case plants and their component opertions utilizing vapour compression distillation as described in 3 above.
9. To estimate ethanol production costs from the vapour compression base case plant designs to determine sensitivity of production csosts as described in 4 above.
10. To prepare estimates of capital, operating and ethanol production costs for vapour compression ethanol plants as described in 5 above.
11. Using life cycle cost and sensitivity analysis for the various alternative process variables investigated, comparative screening will give an economic ranking with respect to type of distilling process & plant throughput & will indicate the most economic size range for potential vapour recompression applications.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1982-83 1983-84	$73,350 $21,000			$73,350 $94,350

CONTINUED

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 353

TITLE Study for the Evaluation of a Single Stage Continuous Airlift Fermenter

CONTRACT # 01843-1-EL10 (OSU81-00512)

CONTRACTOR
Technial University of N.S.
P.O. Box 1000
Halifax, Nova Scotia
B3A 3X4

PRINCIPAL INVESTIGATOR
R.G. Woodside
Centre for Energy Studies
Tel.: 429-8300 Ext. 113

PROGRAM IDENTIFICATION
4.3.8.2
Socio-Economic-Technical Studies/
Technology Assessment

DURATION March 1982 - March 1984

COST $119,107

SPONSOR
Agriculture Canada
(Liquid Fuels Task)

SCIENTIFIC AUTHORITY
E. Manolakis
Engineering & Statistical
Research Institute
Research Branch
Agriculture Canada
Building #94
Central Experimental Farm
Ottawa, Ontario
K1A 0C6

OBJECTIVE

The evaluation of an airlift fermenter for the production of alcohol.

DESCRIPTION

The contractor is to make arrangements for delivery of an airlift fermenter, designed and constructed at the University of Manchester, U.K. and the construction of raw material preparation equipment at the Centre for Energy Studies.

Using a single strain of flocculent yeast (and others, if required) the fermentation system will be optimized and evaluated on the following feedstocks: potato culls, potato processing waste, cheese whey, barley, and fodder beet or other comparable energy crop. Cellulose hydrolysate may also be evaluated if time permits and the Scientific Authority can make arrangements for delivery from a separate study.

The contractor is to perform a technical and economic systems analysis and assessment of alcohol fuel production plants for approximately 900,000 L/a and 5,000,000 L/a scale of operation based on the airlift fermenter concept and compare to conventional batch fermentation.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1981-82	$ 5,000			$ 5,000
1982-83	$ 57,000			$ 62,000
1983-84	$ 57,107			$119,107

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 355

TITLE Extractive Fermentation Using Fluorinated Hydrocarbons

CONTRACT # 0SSX.31926-3-0049

CONTRACTOR
Eco-Research Inc.
121, blvd Hymus
Pointe Claire, Québec
H9R 1E6

PRINCIPAL INVESTIGATOR F.T.T. Tran
Tel.: (514) 697-3273

PROGRAM IDENTIFICATION 4.3.8.2
Socio-Economic-Technical Studies/Technology Assessment

DURATION April 1983 - March 1984

COST $62,000

SPONSOR
Bioenergy Program
National Research Council
(Liquid Fuels Task)

SCIENTIFIC AUTHORITY
S. Hasnain
National Research Council
Montreal Road
Building R-105, Rm 138
Ottawa, Ontario
K1A 0R6
Tel.: (613) 993-1342

OBJECTIVE

To evaluate a range of halogenated hydrocarbons for use as extractants in extractive fermentation to alcohol.

DESCRIPTION

1. Select a range of extractants on the basis of potential extractive efficiency.
2. Screen the compounds for toxicity to selected micro-organisms, extractive efficiency, and water solubility.
3. Report on data obtained and prepare a preliminary feasibility study of this approach including energy analysis and economic evaluation.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$62,000			$62,000

REPORTS

Eco-Research (Canada) Inc. [illegible]tractive Fermentation Using Fluorinated Hydrocarbons." Final Report April, 1984.

STATUS AND COMMENT

Completed

PROJECT DATA SHEET #	383	**PROGRAM IDENTIFICATION**	4.3.8.2 Socio-Economic-Technical Studies/ Technical Assessment
TITLE	Technical Evaluation of Waterloo Fast Pyrolysis Process		
CONTRACT #	31926-3-5026 (OST83-00254)	**DURATION**	October 1983 - November 1985
CONTRACTOR	University of Waterloo Faculty of Engineering Waterloo, Ontario N2L 3G1	**COST**	$269,840
		SPONSOR	Bioenergy Program National Research Council
PRINCIPAL INVESTIGATOR	D.S. Scott Tele.: (519) 885-1211	**SCIENTIFIC AUTHORITY**	R.P. Overend Divsion of Energy National Research Council Building R-105, Rm 135 Ottawa, Ontario K1P OR6 Tele.: (613) 993-1342

OBJECTIVE

There are two major objectives for further development of this successful process at its present small pilot plant stage:

1. To optimize the process for maximum energy efficiency, yield, and product quality.
2. To evaluate possible uses of the product and to test separation and upgrading alternatives.

To these objectives a third one can be added, primarily directed to bench scale research, but also involving some pilot plant tests

3. To develop pre-treatment of the raw material as a means of controlling nature of the products, using results of fundamental work reported in the literature (Shafizadeh and Stevenson, 1982)

DESCRIPTION

1. A set of experiments in which feed rate is varied at constant operating conditions using poplar sawdust, air dried, -30 mesh.
2. A statistically designed set of experiments, intended to locate optimal conditions, in which four variables are manipulated - temperature, residence time, particle size and quench level. These are done using one wood (poplar-aspen) and one agricultural residue (wheat straw or corn stover). Product quality measurements to be made concurrently. Heat transfer measurements to be made in some runs. Experiment design to be discussed with S.A. prior to initiation of the experimental series.
3. Evaluation of liquid yields and composition for 3 alternate feedstocks:
   a) Softwood (spruce or pine).
   b) Agricultural residue - either corn stover or wheat chaff.
   c) Peat - likely to be University de Sherbrooke dewatered - to be discussed with S.A.
4. A set of experiments with wood sawdust feed to determine the effect on process operation and product quality of moisture content in the feed.
5. Two sets of experiments using poplar-aspen, near the optimal conditions found in (2), but using two different catalysts in the fluid bed e.g. a zeolite and a metallic catalyst.
6. Construction, installation and testing of a liquid scrubber.
7. a) Hydrogenation of heavy tar fraction isolated by either distillation and/or solvent washing and extraction.
   b) Hydrogenation of whole oil - liquid and vapour phase.
   c) Product analyst of hydrogenated whole oils.
8. Formation and isolation of derivatives and evaluation of substitution properties.
9. Evaluation of tar and tar fractions for Mutogenic properties (to be performed by an independent testing laborabory).
10. Conversion of tars to fermentable sugars by detoxification and hydrolysis.
11. Assessment of pre-hydrolysis of wood, followed by pyrolysis to produce xyloses and glucose (Shafizadeh process).
12. a) Establish with CCRL (Bell's Corners, Ottawa) the appropriate criteria and tests necessary to qualify the tars and their fractionated products as boiler fuels.
    b) conduct limited firing tests at an appropriate scale.
    c) Evaluate fuel storage stability - including the addition of necessary stabilizers to satisfy fuel standards.
13. Long duration continuous operation at optimal conditions.
14. Cold flow experimental modelling of a compartmentalized shallow fluidized bed.
15. Engineering technical feasibility study and economic evaluation of a conceptual process. Identification of key factors in scale-up and in economic viability.
16. Preparation of Final Report.

NOTE that, because the pilot plant exists in a fully operational state with its own biomass grinding and drying facilities that work on the above tasks can commence at once with no preparation time necessary.

CONTINUED

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84 1984-85 1985-86	$ 65.000 $130.000 $ 74.840			$ 65.000 $195.000 $269.840

REPORTS

SCOTT D.S. and PISKORZ J., "The Waterloo Fast Pyrolysis Process for the Production of Liquids from Biomass," in Proc. of the Fifth Canadian Bioenergy R&D Seminar/Cinquième séminaire canadien R&D bioénergétiques, Ottawa, Ontario, Mar 26-28, 1984.

SCOTT D.S. and PISKORZ J., "The Continuous Flash Pyrolysis of Biomass," in Proc. of Comptes rendus de l'atelier de travail sur la liquéfaction de la biomasse, Sherbrooke, Quebec, Sept. 29-30, 1983

STATUS AND COMMENT

Work is on schedule and proceeding well

R.P.D. 84/11/29

PROJECT DATA SHEET # 461

TITLE
Economic Model for the
Production of Liquid
Fuels From Agricultural Biomass

CONTRACT # E2062 EL31

CONTRACTOR
W.L. Wardrop & Assoc. Ltd.
77 Main Street
Winnipeg, Manitoba
R3C 3H1

PRINCIPAL INVESTIGATOR H. Husain

PROGRAM IDENTIFICATION
4.3.8.2
Socio-Economic-Technical
Studies/
Technologies
Assessment

DURATION April 1983 - March 1985

COST $35,000

SPONSOR Agriculture Canada

SCIENTIFIC AUTHORITY
B. Kennedy
Energy, Mines & Resources
Energy Analyst
Room 726
460. O'Connor Street
Ottawa, Ontario
K1A 0E4
Tele.: (613) 995-9447

OBJECTIVE

To develop an economic model of liquid fuels production from agricultural biomass.

DESCRIPTION

Computer analysis and modification of an existing Wardrop program to prepare charts, graphs and nomographs that show the effect of changes in various cost parameters and are independent of current prices. The model will include farming costs, feedstock prices (energy crops, grains, oilseeds, cellulosic residues) by product prices and values, processes, material and energy balances and liquid fuel options (ethanol, butanol, vegetable oils and derivatives, and plant derived hydrocarbons.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1983-84	$12,000			$12,000
1984-85	$23,000			$35,000

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET #	463
TITLE	Whole Plant Oils: A Potential Renewable Fuel Extender
CONTRACT #	01916-3-EL23
CONTRACTOR	Enersearch Federated Co-op Ltd. 401-22nd Street East P.O. Box 1050 Saskatoon, Saskatchewan S7K 3M9
PRINCIPAL INVESTIGATOR	W.K. Craig
PROGRAM IDENTIFICATION	4.3.8.2 Socio-Economic-Technical Studies/Technology Assessmemt
DURATION	December 1983 - December 1985
COST	$165,000
SPONSOR	Agriculture Canada
SCIENTIFIC AUTHORITY	M. Stumborg Agriculture Canada Research Station Box 1030 Swift Current, Saskatchewan S9H 3X2

OBJECTIVE

1. To determine the amount of whole plant oils that can be extracted from alfalfa, sweet clover, kochia, and steam exploded wood and to evaluate the use of the extracted product as
    - a) a direct extender of diesel fuel,
    - b) a precursor to a gasoline octane improver/gasoline extender, and
    - c) a refinery feedstock for the production of specification liquid fuels.
2. To evaluate the quality of the residual material as an animal feed and fermentation material.
3. To evaluate the plant oil extract as a co-solvent with methanol in diesel fuel.
4. Economic and technical assessment of the potential of whole plant oils from conventional forages.

DESCRIPTION

Laboratory scale extractions of oils from conventional (alfalfa, sweet clover) and unconventional (kochia, steam exploded wood) biomass feedstocks using methanol or other solvents (SRC); chemical analysis of major classes of compounds in extracts plus CHNO content, colorific value etc. (SRC); pilot plant methanol extraction of alfalfa (POS); laboratory evaluation of lab scale oil extracted residues as animal feed (SRC), ruminant animal feed trial of extracted alfalfa residue (U of S); evaluation of solvent extracted alfalfa and steam exploded wood as a hydrolysis and fermentation feedstock (Forentek, M. Wayman); alfalfa and milkweed HC's (Contract ER02) from pilot plant extractions blended with diesel fuel and small chain alcohols will undergo standard specification tests and engine testing in a single cylinder diesel engine with dynamometer (Enersearch); alfalfa oils assessed as a refinery feedstock (U.O.P.) and other extracts, if promising; evaluation of alfalfa and steam exploded wood oils as a precursor for octane improvers (Enersearch); economic assessment, energy inputs, outputs (SRC Enersearch).

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1983-84	$25,000			$ 25,000
1984-85	$80,000			$105,000
1985-86	$60,000			$165,000

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 399

TITLE Establish the Technical and Economic Feasibility of Large Scale Enzyme Production using Chemical Grade Feedstock and the P-37 Organism

CONTRACT # 23216-3-6264 (OSQ83-00126)
C-378

CONTRACTOR
Iotech Corp. Ltd.
400 Hunt Club Road
R.R. 5
Gloucester, Ontario
K1G 3N3

PRINCIPAL INVESTIGATOR P.W. Smith

PROGRAM IDENTIFICATION 4.3.8.3
Socio-Economic-Technical Studies/
Economic Assessment

DURATION April 1983 - May 1984

COST $113,700

SPONSOR Energy, Mines & Resources

SCIENTIFIC AUTHORITY
A.J. Dolenko
Renewable Energy Division
Energy, Mines and Resources
580 Booth Street
Ottawa, Ontario
K1A OE4
Tele.: (613) 995-9447

OBJECTIVE

Confirm current lab and pilot plant enzyme productivity levels of 100 IU/litre-hr in 2000 gallon (working volume) fermentors using commercially practical operating conditions.
Prepare biomass conversion production plant capital and operating projections based on these scale-up results.

DESCRIPTION

Based on our discussions at Corning and our recent discussion with Messrs. Hogan and Dolenko, Iotech proposes that the test work described herein be undertaken in three phases.

1) substrate preparation.
2) one or two sequential 1000 gallon fermentor runs.
3) one or two 2000 gallon fermentor runs depending on results from the previous run(s).

A total of three runs would be undertaken.
This approach allows testing of the additional modest scale-up step from 1000 to 2000 gallons with the added value of an additional data point for oxygen transfer and mixing requirements relevant to final design. In addition, both Iotech and Corning personnel believe there is considerable value in being able to demonstrate run consistency in back-to-back trials at a given scale. Finally, the option to terminate the runs after the first 1000 gallon scale test exists if unforeseen problems do arise.
Chemical grade substrate will provide significantly better enzyme yields and will be consistent with what we will use in our pilot plant program. Because it is a finer grade material it takes slightly longer to produce and extract than our standard feed grade material.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1983-84 1984-85	$ 78,700 $ 35,000			$ 78,700 $113,700

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 422

TITLE	Testing and Analysis of the Recovery and Transport of Roadside Biomass in Mountainous Terrain
CONTRACT #	KH603-3-0024(0SB83-00123) P-251
CONTRACTOR	Forest Engineering Research Institute of Canada Suite 201-2112 West Broadway Vancouver, B.C. V6K 2C8
PROGRAM IDENTIFICATION	4.3.8.3 Socio-Economic-Technical Studies/Economic Assessment
DURATION	May 1983 - November 1983
COST	$94,638
SPONSOR	Environment Canada
SCIENTIFIC AUTHORITY	G.H. Manning Pacific Forest Research Centre Canadian Forest Service 506 West Burnside Road Victoria, British Columbia V8Z 1M5 Tele.: (604) 388-3811

OBJECTIVE

1. To document and compare the costs and productivity of recovering and transporting two different standards of roadside biomass using the conventional, self-loading logging truck.
2. To document the costs and productivity of recovering and transporting roadside biomass with new machines and methods that operate concurrently with active logging.

DESCRIPTION

1. During three weeks of shift level monitoring determine the productivity of each of the systems. Measure fuel consumption throughout the period.
2. Scale the biomass recovered after it has been delivered to the log sortyard.
3. In selected test area scale the roadside biomass before and after recovery has been made.
4. Calculate the productivity and costs of each of the systems and compare them.
5. Publish a report on the tests that can be used as a guide when selecting biomass recovery and transportation machines and systems.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$94,638			$94,638

REPORTS

Recovery and Transport of Roadside Biomass in Mountainous Terrain - Final Contract Report.

STATUS AND COMMENT

Completed March 31, 1984.

84/12/06

PROJECT DATA SHEET # 424

TITLE Socio-Economic Impact of an Integrated Fuel and Fibre Production and Merchandising System for the British Columbia Coast

CONTRACT # KH603-3-0022(05B83-00082)
P-253

CONTRACTOR
Nawitka Renewable Resource Consultants Ltd.
836-840 Cormorant Street
Victoria, B.C.
V8W 1R1

PROGRAM IDENTIFICATION 4.3.8.3
Socio-Economic-Technical Studies/Economic Assessment

DURATION April 1983 - March 1985

COST $59,205

SPONSOR Environment Canada

SCIENTIFIC AUTHORITY
G.H. Manning
Pacific Forest Research Centre
Canadian Forest Service
506 West Burnside Road
Victoria, British Columbia
V8Z 1M5
Tele.: (604) 388-3811

OBJECTIVE

1. (a) To identify the wood wastes (hog fuel or burnables) available to a large integrated forest products manufacturing complex on north Vancouver Island.
   (b) To identify the additional burnable forest biomass that would be available under improved utilization where increased integrated fuel and fibre production are planned.
2. To indicate the costs associated with increased integrated fuel and fibre production for a major coastal operation.
3. To indicate the corporate benefits associated with the increased fuel and fibre production.
4. To show and evaluate the regional socio-economic costs and/or benefits of increased integrated production at two or more levels of scale (i.e. one operation or company versus several).

DESCRIPTION

The approach proposed is that of a consultant working closely with a major B.C. coastal forest products company in identifying the potential for expanding integrated fuel and fibre operations on North Vancouver Island.

The proposal is in two parts. Phase I (1983-84) would be in support of defining the amounts of fuel and fibre available or necessary, product mix, and feasible production levels given the costs and prices involved for forest products as well as alternative energy sources. This phase is directed at identifying feasible production alternatives including scale.

Phase II (1984-85) would be in support of identifying selected feasible alternatives in terms of both corporate benefits and regional socio-economic costs and benefits.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1983-84 1984-85	$25,000 $34,705			$25,000 $59,705

REPORTS

STATUS AND COMMENT

To be completed March 31, 1985

84/12/06

PROJECT DATA SHEET # 449

TITLE
Economic Evaluation of Wood Chip Production Alternatives for Prince Edward Island

CONTRACT #
KH209-3-0233(OSC83-00645)
P-292

CONTRACTOR
IEA Consulting Group Ltd.
P.O. Box 2888
Charlottetown, P.E.I
C1A 8C5

PRINCIPAL INVESTIGATOR
G.W. Mason

PROGRAM IDENTIFICATION
4.3.8.3
Socio-Economic-Technologies Studies/Economic Assessment

DURATION
January 1984 - February 1985

COST
$29.239

SPONSOR
Environment

SCIENTIFIC AUTHORITY
G. Van Raalte
Maritimes Forest Research Centre
Canadian Forest Service
Box 4000
Fredericton, New Brunswick
E3B 5P7
Tele.: (506) 452-3519

OBJECTIVE

To examine the various wood fuel supply systems currently in use in P.E.I. and make recommendations regarding how producers can lower costs, increase the chip fuel market and improve returns.
To analyze the economics of establishing centralized processing facilities for the production of wood chips with emphasis on material storage, drying, handling and transportation.

DESCRIPTION

The contractor will identify and interview local (P.E.I.) producers to determine the supply systems currently in use, the costs of these systems and the production costs per unit of chips.
The contractor will carry out a literature review to examine wood fuel chip production systems in use in other areas including Canada, Scandinavia and the U.S.A.
The contractor will perform economic evaluations to determine the lowest cost production/transportation systems for different scales of a magnitude compatible to the P.E.I. situation.
The contractor will evaluate and make recommendations as to the most economical design and location of centralized chip production depots for the different scales of operations identified above.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1983-84	$ 6.755			$ 6.755
1984-85	$22.484			$29.239

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 450

TITLE Preparation of Economic Forecasts for Oil and Natural Gas, Relevant to British Columbia Pulp and Paper Mills

CONTRACT # KH603-3-1106(OSB83-00555)
P-293

CONTRACTOR
Robinson Consulting & Assoc Ltd
2526 Government Street
Victoria, British Columbia
V8T 4P7

PROGRAM IDENTIFICATION 4 3 B 3
Socio-Economic-Technical Studies/Economic Assessment

DURATION January 1984 - March 1984

COST $6,850

SPONSOR Environment Canada

SCIENTIFIC AUTHORITY
G H Manning
Pacific Forest Research Centre
Canadian Forest Service
506 West Burnside Road
Victoria, British Columbia
V8Z 1M5
Tele (604) 388-3811

OBJECTIVE

The purpose of the study is to provide forecasts of heavy fuel oil and natural gas prices which incorporate the most recent outlook for world oil prices and government pricing policies Given information regarding the delivered cost of biomass, the price forecast developed in this study will assist in predicting future trends in biomass use

DESCRIPTION

The study can be broken into five distinct phases and within each phase several tasks are identified

A World and Domestic Oil Price Forecast
The domestic oil price is a blend of the wellhead price of old conventional crude oil the wellhead price of new enhanced and synthetic oil, plus a number of taxes and tariffs We would not attempt to develope an oil price forecast for this study, but will rely on the forecast developed by EMR, and others EMR will be contacted during this phase as well as other appropriate forecasting agencies and an oil price forecast adopted This phase is expected to require three days

B Industrial Natural Gas Price Forecast
The stated provincial government policy is to move the average provincial wholesale natural gas price to 65% of the energy equivalent cost of crude oil at the Vancouver refinery gate by 1990 From the domestic oil price forecast(s) adopted above, the average gas wholesale price must then be separated into the particular wholesale price to the relevant distribution utility, to which a distribution margin must be estimated to derive the interuptible natural gas rate to industrial users The particular distribution utility wholesale price forecast and distribution margins will be estimated by referring to the present rate structure, and with reference to the future demand for gas This phase is expected to require five days

C Heavy Fuel Oil Price Forecast
Heavy fuel oil is currently the primary fossil fuel of the coastal pulp mills not served by natural gas The fuel is purchased from domestic (Lower Mainland) refiners and imported The study will proceed by briefly reviewing the current and future outlook for the HFO market Based on this review, the price of heavy fuel oil will be linked to either the international oil price, or the domestic oil price, whichever is deemed more appropriate This phase of the study will rely on the recent testimony given before the B C Utilities Commission public hearing regarding the heavy fuel oil market Two days have been allocated to this task

D Vancouver Island Natural Gas Pipeline
The proposed pipeline could potentially serve five pulp mills that currently meet their energy requirements with a mix of heavy fuel oil This price discount effectively lowers the incremental price mills might be willing to pay for biomass Testimony and reference material from the Utilities Commission hearing will be used to forecast the expected Island natural gas price Two days are required for this phase

E Report Preparation
The report will present a natural gas and/or heavy fuel oil price forecast for each provincial pulp mill The price forecast will also be converted into an equivalent cost per unit of delivered biomass using the range of boiler efficiencies provided by the Canadian Forest Service It is proposed that an initial draft be prepared and discussed before the final report is submitted Three days are expected to complete this task

CONTINUED

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$6,850			$6,850

REPORTS

"Price forecasts of Heavy Fuel Oil and Natural Gas relevant to the B.C. Pulp and Paper Mills (1984-2000) Impact on Biomass Values." Final Contract Report

STATUS AND COMMENT

Completed March 31, 1984

84/12/06

PROJECT DATA SHEET # 484

TITLE A Comparison of the Costs of Transportation Fuel from many Methanol Plants Versus a Single Oil Sands Plant

CONTRACT # 31926-3-0099(DSG83-00124)

CONTRACTOR
Canadian Energy Research Inst
3512-33 Street North West
Calgary, Alberta
T2L 2A6

PRINCIPAL INVESTIGATOR
B.D. Sumner
T. Gibson
Z.C. Slagorsky

PROGRAM IDENTIFICATION
4.3.8.3
Socio-Economic-Technical Studies/ Economic Assessment

DURATION November 1983 - August 1984

COST $49,960

SPONSOR
Bioenergy Program
National Research Coun[illegible]
Energy, Mines a[illegible]ces
Office of Energ[illegible]

SCIENTIFIC AUTHORITY
René Pigeon
National Research Council
Division of Energy
Building R-105, Rm 136
Ottawa, Ontario
K1A 0R6
Tele.: (613) 993-1028

OBJECTIVE

To estimate and compare the overall social cost of generated energy (in $/GJ) between the Syncrude oil sands plant and several smaller-scale (max. output 400 kt/a) methanol plants; similar to Ocelot's at Kitimat, B.C.; giving the same total energy output. The methanol plants would be assumed to use natural gas as feedstock. The returns to scale and the economic risks of both types of projects will be examined . Sensitivity to alternative cash flow schedule and capital cost reduction of several plants built successively will be evaluated.
The fuel from the alternative supply systems will be compared at the same delivery points but not at the same rate of supply. Regional income and employment impacts of the construction phase of each option will be evaluated using the input-output model of Statistics Canada.

DESCRIPTION

Both types of projects begin full-scale production before the end of the 1970s. The analysis will be completed in 1982 $ with a series of methanol plants to be located across Canada along the current natural gas distribution network. Supply prices evaluated as social cost to the Canadian economy excludes taxes and financial costs. Refinery gate blending of methanol and gasoline will be assumed. Refinery gate pricing (1982 $) will also be used to compare gasoline costs from Syncrude including pipeline cost to refineries in Montreal, Toronto and Edmonton and blending cost versus the costs of a methanol-gasoline blend in the 3 local markets. In order to compare the 2 options on the same basis as substitutes for imported oil, the energy production has been made up with complementary volumes of gasoline for the early and late years when one option does not produce the same energy output.
With respect to the goal of self-sufficiency, methanol can displace the need for imported oil supply for transportation fuel. Given a 5-10 percent blend, the potential for methanol is limited by the local market for gasoline. The potential market for methanol can be estimated as a percentage of gasoline demand for major centers along the natural gas pipeline.
Calculation procedures should involve the following steps:

1) Supply prices for the Syncrude plant and methanol fuel systems will be calculated using the 3 above mentioned cities: a) as delivery points for the refined syncrude product and b) as a common location for the equivalent methanol plants.
2) Variations in the methanol supply price associated with effects of varying cost outlays and revenues on the supply price.
3) Costs of transporting natural gas to methanol plants located at 3 different cities along the pipeline consistent with regional pricing regulations for natural gas and the transportation cost of synthetic crude refined into gasoline at different cities.
4) Adjust the supply costs of synthetic crude refined into gasoline versus methanol plants' fuel for cities along the pipeline for the cost reductions associated with many small scale plants: a) commercialization learning curve reducing capital costs associated with many plants, and b) shorter lead time for production with small plants.

CONTINUED

FUNDING

FISCAL YEAR	SPONSOR	EMR		CUMULATIVE TOTAL
1983-84	$24,960	$25,000		$49,960

REPORTS

"A Comparison of the Costs of Transportation Fuel from Many Methanol Plants Versus a Single Oil Sands Plant," CERI, 1984, 98 p., 18 copies have been distributed including one the to CISTI library. 40 copies have been ordered for further distribution.

STATUS AND COMMENT

With a cost breakdown of the methanol plant, the cost of methanol from gasified biomass could be substituted for natural gas reforming. Comments were made by EMR (L. Good) and NEB (P. Miles) for using the export price of natural gas as its social opportunity cost instead of the lower values used in the study capital cost reductions from replication of standard plants has been only assumed, it could be analyzed more deeply. This effect could be larger if a hundred plants were needed to meet a neat methanol market instead of 3 plants for 5% blending with gasoline. A more explicit evaluation of the different explanatory factors would be illuminating: starting with supply prices for a single location and time, adding the effect of early revenues when several plants are built sequentially, adding then the cost differences due to transporting bitumen and natural gas to different markets, and including the capital cost learning curve.

84/11"29

PROJECT DATA SHEET # 255

TITLE Comparative Assessment of Forest Biomass Conversion to Energy Forms

CONTRACT # KN107-1-4416 (05581-00228)
C-258

CONTRACTOR H.A. Simons (Int'l) Ltd.
Consulting Engineers
425 Carrall Street
Vancouver, British Columbia
V6B 2J6

PRINCIPAL INVESTIGATOR J. Elliott
B.H. Levelton

PROGRAM IDENTIFICATION 4.3.8.4
Socio-Economic-Technical Studies/Information

DURATION April 1982 - March 1984

COST $798.655

SPONSOR Environment Canada

SCIENTIFIC AUTHORITY R.P. Overend
National Research Council Canada
Building R-105, Rm 135
Ottawa, Ontario
K1A 0R6
Tel.: (613) 993-1342

OBJECTIVE

The objective of this requirement is to pull together conversion process data into a single source. Both existing and near term technology for the conversion of forest biomass into usable forms of energy will be covered. This report will assist government and industry in making decisions regarding the provision of facilities generating alternate forms of energy.

DESCRIPTION

Utilizing literature surveys, direct contacts and other available means, the contractor shall prepare a critical evaluation of the several unit processes that are the basis of complete forest biomass to fuel production conversion plants.

Examples of unit processes are: comminution, drying, solid fuel preparation, combusters, low joule gas (LJV), medium joule gas (MJV), gas clean up, synthetic gas production, etc.

The evaluations shall reflect the Energy from Forest (ENFOR) Program results and data plus the experience of other countries. The unit processes are to be assembled into complete systems such as production of process steam, application of hot gases and/or LJV in kiln drying, lime kilns and chemical processes.

Utilization of synthetic gas to produce methanol and ammonia, and ethanol production by fermentation, are to be considered.

The work will be reported in the form of a series of Data volumes using the unit process concept.

Costing will generally be developed as a parametric description enabling users to identify appropriate size ranges and then to develop their own costing to curve.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1982-83 1983-84	$503.062 $295.593			$503.062 $798.655

CONTINUED

REPORTS

A Comparative Assessment of Forest Biomass Conversion to Energy Forms.
Phase I: "Proven and Near-Proven Technology."
    Vol. I: "Introduction, Summary and Findings".
    Vol. II: "The Unit Process Approach to Energy Systems, Technical Background Data, and Bases for Process Evaluations".
    Vol. III: "Data Book of Unit Processes for Fuel Preparation and Handling".
    Vol. IV: "Data Book of Unit Processes for Primary Conversion by Direct Combustion".
    Vol. V: "Data Book of Unit Processes for Primary Conversion by Thermal, Chemical and Biological Methods".
    Vol. VI: "Data Book of Unit Processes for Modification and Upgrading of Energy Forms.
    Vol. VII: "Data Book of Unit Processes for Pollution Control".
    Vol. VIII: "Data Book of Unit Processes for Secondary Conversion of Energy Forms".
    Vol. IX: "Systems for Utilization of Biomass Fuels".
Phase II: "Emerging Technology and an Update of proven and Near-Proven Technology".
    Vol. VIa: "Data Book of Unit Processes for Modification and Upgrading of Energy Forms.
    Vol. Va: "Data Book of Unit Processes for Primary Conversion by Thermal, Chemical, and Biological Methods".

The reports are available to Canadians through the ENFOR Conversion Secretariat, Bioenergy Development Program, Renewable Energy Division, Energy, Mines and Resources Canada, 580 Booth Street, Ottawa, Ontario, K1A 0E4.
Non-Canadians may purchase the reports through the contractor.

STATUS AND COMMENT

Work in progress - very slightly delayed. See Data sheet 500, Development of a Computer Model to Simulate Bioenergy Conversion Systems", which is based on this study.
R.P.D. 84/12/01

PROJECT DATA SHEET #	364	**PROGRAM IDENTIFICATION**	4.3.8.4 Socio-Economic-Technical Studies/Information
TITLE	Standard Reference Materials & Sample Banks for Research, Development & Commercial Applications of Biomass for Fuels and Chemicals	**DURATION**	September 1983 - September 1984
		COST	$18,494
CONTRACT #	31926-3-5002 (05X83-00098)	**SPONSOR**	Bioenergy Program National Research Council
CONTRACTOR	Solar Energy Research Institute 1617 Cole Blvd. Golden, Colarado U.S.A. 80401	**SCIENTIFIC AUTHORITY**	R.P. Overend National Research Council Division of Energy Building R-105, Rm 135 Ottawa, Ontario K1A OR6 Tele.: (613) 993-1342
PRINCIPAL INVESTIGATOR	T.A. Milne		

OBJECTIVE

The contractor proposes to spend a year at the National Bureau of Standards, in the Office of Standard Reference Materials, working with NBS staff. He will define, and prepare a proposal to secure funds for, a continuing program at the Bureau that addresses the needs of the research, development and commercial applications communities for well-characterized and reproductible biomass materials.

DESCRIPTION

Task 1: Work with personnel of the Office of Standard Reference Materials, and other apporpriate NBS staff, in planning the needs of the biomass community for reference materials and sample banks, and the nature of such materials. (70% of time)

Task 2: Guide, and interpret data from, DOE-sponsored ongoing pyrolysis research at SERI. (20% of time)

Task 3: Review and assist long-range planning for the Thermochemical and Electrochemical Branch's other research tasks. (10% of time)

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$18,494			$18,494

REPORTS

Workshop was held at the NBS Aug 1-3, 1984. Proceedings are published by SERI in SERI-CP-234-2506, "Workshop on Standards in Biomass for Energy and Chemicals", Nov 1984. Copies may be obtained by contacting SERI.

STATUS AND COMMENT

The workshops made several recommendetion which will be the subject of the future joint US/Canada work and in the IEA. The Canadian R&D Program will have available to it a significant quantity of standard wood for conversion R&D - see Data Sheet # 523.

84/12/01

PROJECT DATA SHEET #	440	**PROGRAM IDENTIFICATION**	4.3.8.4 Socio-Economic-Technical Studies/Information
TITLE	Preparation of a Terminology Relating to Forest Biomass for Energy	**DURATION**	June 1983 - March 1984
CONTRACT #	KN107-3-4187(05583-00047) P-280	**COST**	$25,000
CONTRACTOR	Forest Engineering Research Institute of Canada 143 Place Frontenac Pointe Claire, Quebec H9R 4Z7	**SPONSOR**	Environment Canada
		SCIENTIFIC AUTHORITY	M. Bowen Canadian Forest Service Environment Canada Ottawa, Ontario K1A 1G5

OBJECTIVE

Prepare a terminology in English and French on forest biomass for energy in general, and on recovery methods, processing and conversion technology.

DESCRIPTION

In recent years and with the increasing importance of forest biomass as a source of energy, it has become more and more difficult to describe adequately the various situations and operations relating to forest biomass for energy. New words are being coined (in many cases they are improper); words are borrowed from other industries; and finally, in many cases, words simply do not exist to describe specific aspects or operations of this new field. Also, there are some real problems in going from French to English and vice-versa. It is therefore timely to develop a "forest biomass terminology" before too much confusion sets in.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$25,000			$25,000

REPORTS

STATUS AND COMMENT

The terminology has not been completed yet, is overdue and is expected to be completed by the end of September, 1984.

84/12/06

PROJECT DATA SHEET # 445

TITLE Preparation of Background Material for Paper: Poplars and Willows

CONTRACT # KN107-3-4326(OSS83-00090)
P-288

CONTRACTOR Poplar Council of Canada
Ontario Ministry of National Resources
Ontario Forest Research Centre
Maple, Ontario
LOJ 1EO

PRINCIPAL INVESTIGATOR R.L. Gambles
L. Zsuffa

PROGRAM IDENTIFICATION 4.3.8.4
Socio-Economic-Technical Studies/Information

DURATION September 1983 - March 1984

COST $13.000

SPONSOR Environment Canada

SCIENTIFIC AUTHORITY R.C. Dobbs
Canadian Forest Service
Chalk River, Ontario
KOJ 1JO

OBJECTIVE

To compile information on the socio-economic impact that utilization of poplars and willows has in Canada.
To prepare the background material for the keynote paper to be presented by Canada at the 17th Session of the International Poplar Commission of the Food and Agriculture Organization of the United Nations (October 1-4, 1984, Ottawa). The mater will cover the topics outlined in the questionnaire issued by the I.P.C. (see attached).

DESCRIPTION

1. Review existing literature to document the historical development of the poplar and willow resource and its utilization.
2. By co-operating with selected Council members who are specialists in their fields from industry, governments and universities, the status of research in progress on poplar and willow will be ascertained.
3. From the historical and current data generated:
   - asses the knowledge of the indigenous species, the conservation of the genetic resource, the breeding programmes, and the protection methods in Canada;
   - develop a listing of poplar and willow using industries;
   - determine jobs and revenues generated by these industries;
   - determine the extent and method of utilization;
   - Evaluate newly developed production systems that have yet to be implemented commercially; and
   - assess the impact of the same in generating new industry, related jobs and economy.
4. Prepare and present a paper at a conference in Ottawa in mid-March, 1984.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$13,000			$13,000

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 452

TITLE Review of Commercial and Industrial Wood/Peat Energy in Atlantic Canada 1978-83 and Beyond

CONTRACT # KH205-3-0178(OSC83-00591)
P-294

CONTRACTOR Northland Associates Ltd.
P.O. Box 1734
13 Prescott Street
St. John's, Newfoundland
A1C 5P5

PROGRAM IDENTIFICATION 4.3.B.4
Socio-Economic-Technical Studies/Information

DURATION January 1984 - March 1984

COST $24,324

SPONSOR Environment Canada
Energy, Mines and Resources

SCIENTIFIC AUTHORITY A.B. Case
Environment Canada
Newfoundland Forest Research Centre
Building 304, Pleasantville
St. John's, Newfoundland
A1C 5X8
Tele.: (702) 772-4806

OBJECTIVE

To summarize the commercial and industrial wood/peat energy developments in Atlantic Canada for the period 1978-1983, and to provide some insight into future developments in the region. For the purposes of this review, Atlantic Canada consists of the provinces of New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland.

DESCRIPTION

A. The consultant shall provide a summary for each commercial, institutional, and industrial application of wood/peat energy in Atlantic Canada. Such summaries shall include, for harvesting and burning operations, the following information:

- Project description
- Location
- Proponent
- Objective
- Funding
- Status
- Costs
- Benefits
- Type of fuel
- Systems used
- Environmental monitoring
- Current results
- Relevent reports

B. In consultation with federal, provincial, and industrial agencies in each province, the consultant shall prepare a summary of proposed future wood/peat energy projects in Atlantic Canada. Where possible, the same information requested on A above, will be provided for each new proposed project.

C. Based on a review of published reports and data, and on the information and "feel" gained through the investigation, the consultant shall report on the future prospects for wood/peat energy development in each province and in Atlantic Canada as a whole. In this analysis, the consultant shall consider:

- the availability of a suitable biomass supply
- problems of distribution
- impact on the forest/peat resource
- the need to educate potential
- socio-economic implications; e.g., employment

D. The consultant shall provide a comprehensive bibliography of all recent literature related to the subject of wood/peat energy in Atlantic Canada.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$24,324			$24,324

REPORTS

"Review of Commercial & Industrial Wood/Peat Energy in Atlantic Canada - 1978/83 and Beyond", Final Contract Report.

CONTINUED

STATUS AND COMMENT

Contract completed. 84/11/29

BIOMASS MATERIALS HANDLING, TRANSPORTATION

PRE-TREATMENT

General

Materials Handling

Transportation

Pre-Treatment

PROJECT DATA SHEET #	397	**PROGRAM IDENTIFICATION**	4.3.9.1 Biomass Materials Handling, Transportation & Pretreatment/ General
TITLE	Production of Poplar Cuttings	**DURATION**	November 1983 - October 1984
CONTRACT #	31926-3-5018 (OSX83-00150)	**COST**	$154,986
CONTRACTOR	Centre de recherche industrielle du Québec 333, rue Franquet Ste-Foy, Québec G1V 4C7	**SPONSOR**	Bioenergy Program National Research Council
PRINCIPAL INVESTIGATOR	M.G. Handfield	**SCIENTIFIC AUTHORITY**	T.B. Golob National Research Council Division of Energy Building R-105, Rm 132 Ottawa, Ontario K1A 0R6 Tele.: (613) 993-1342

OBJECTIVE

DESCRIPTION

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$154,986			$154,986

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 154		**PROGRAM IDENTIFICATION**	4.3.9.2 Biomass Materials Handling, Transportation & Pretreatment/ Materials Handling
TITLE	Bin and Silo Design for Biomass Materials		
CONTRACT #	KL229-0-4120 (DSS80-43) C130	**DURATION**	April 1980 - March 1984
CONTRACTOR	B.C. Research 3650 Wesbrook Mall Vancouver, B.C. V6S 2L2	**COST**	$496,073
		SPONSOR	Energy, Mines & Resources
PRINCIPAL INVESTIGATOR	N. Bundalli	**SCIENTIFIC AUTHORITY**	A.J. Dolenko Conservation & Renewable Energy, Mines and Resources 460 O'Connor Ottawa, Ontario K1A 0E4 Tele.: (613) 995-9447

OBJECTIVE

1. To design and construct a shear testing apparatus suitable for biomass materials in order to obtain data necessary for better design of bins and silos used for storing such materials.
2. To test different types of biomass materials under varying conditions so as to make suitable recommendations on bin and silo design as well as material conditioning (where appropriate) to achieve uninterrupted and uniform discharge.
3. To identify factors which contribute to poor flow properties.

DESCRIPTION

A shear testing apparatus with a large enough cell to hold sufficient quantity of a woodwaste material will be designed in detail.

The apparatus will have some of the features of the Jenike Tester but with a cell diameter of 76.2 cm. Shearing will be carried out by pulling the top half of the cell by means of a steel cable-attached to the cell, preferably at a constant rate to achieve a steady strain rate. The stress required to shear the material will be measured by a suitable tensile transducer connected to the steel cable.

For wall friction tests, the bottom cell ring will be replaced by a plate of the bin wall material to be tested. Several plates will be made up of different construction materials, some with special linings used to reduce wall friction.

Several extra cells will be made up to carry out time consolidation tests to determine the effect on the flow properties of storing woodwaste materials in bins over periods of time without discharging. Since individual components of the apparatus are likely to be of considerable weight and size, adequate provision will be made for lifting and manoeuvring the items with ease.

Following construction of the shear testing apparatus, some trial tests will be carried out to check the equipment for proper functioning. Any necessary modifications will be done.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1980-81	$115,100			$115,100
1981-82	$123,467			$238,567
1982-83	$140,506			$379,073
1983-84	$117,000			$496,073

REPORTS

BUNDALLI N., MARTINEZ D., B.C. Research, "Bin and Silo Design for Biomass Materials," Vancouver, B.C., July 1982. ENFOR Project C-130. (Available from ENFOR Secretariat)

CONTINUED

STATUS AND COMMENT

The contract is to include an examination of the effects of cold weather conditions and also study the storage of peat.

84/12/04

PROJECT DATA SHEET #	308	**PROGRAM IDENTIFICATION**	4.3.9.2 Biomass Materials Handling, Transportation and Pretreatment/ Materials Handling
TITLE	Development of a Feed Mechanism for Straw Burners		
CONTRACT #	01843-1-ER12 (OSZ81-00130)	**DURATION**	February 1982 - March 1984
CONTRACTOR	Biomass Combustion Ltd. Canning, Nova Scotia BOP 1HO	**COST**	$79,236
		SPONSOR	Agriculture Canada
PRINCIPAL INVESTIGATOR	J. Peill	**SCIENTIFIC AUTHORITY**	D. Marshall Engineering and Statistical Research Institute Research Branch Agriculture Canada Ottawa, Ontario K1A OC6 Tel.: (613) 995-9671

OBJECTIVE

DESCRIPTION

Evaluation of engineering alternatives

A. Bale Dissolver Options
1. Loose flail type
2. Fixed flail type
3. Auger with cutting edge type
4. Rotating disc type
5. Gang saw type
6. Multiple circular saw type
7. Tub grinder type

B. Stoker Options
1. Single auger and best configuration
2. Double auger and best configuration
3. Hydraulic ram type
4. Mechanical ram type

C. Back Burn Preventer
1. For single auger-water or mechanical plus suitable sensing device
2. For double auger-water or mechanical plus suitable sensing device
3. For ram types-water or mechanical plus suitable sensing device

D. Select components, complete fabrication drawings of chosen design and fabricate, install and monitor operation.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1981-82	$15,227			$15,227
1982-83	$56,009			$71,236
1983-84	$ 5,000			$76,236
1984-85	$ 3,000			$79,236

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET #	324	**PROGRAM IDENTIFICATION**	4.3.9.2 Biomass Materials Handling, Transportation & PreTreatment/ Materials Handling
TITLE	Further Development & Improvement of a Dense Phase Pneumatic Conveying System for Biomass Material	**DURATION**	May 1982 - January 1985
CONTRACT #	KN107-2-4081 (DSS83-00172) C-273	**COST**	$232,800
CONTRACTOR	B.C. Research 3650 Wesbrook Mall Vancouver, B.C. V6S 2L2	**SPONSOR**	Energy, Mines & Resources
PRINCIPAL INVESTIGATOR	N. Bundalli Tel.: (604) 224-4331	**SCIENTIFIC AUTHORITY**	A.J. Dolenko Conservation & Renewable Energy, Mines and Resources 460 O'Connor Street Ottawa, Ontario K1A 0E4 Tele.: (613) 995-9447

OBJECTIVE

To develop a pneumatic conveying system for hog fuel and other biomass materials which will have considerably lower air requirements and would operate at lower conveying velocities.

DESCRIPTION

A pilot scale pneumatic conveying system will be designed by B.C. Research and ACD Sales and assembled at B.C. Research. The system will be of the "Pulse Flow" type where the material is separated into plugs by air cushions. Such a system has been developed in the U.K. for domestic refuse and operates at much lower air velocities.
Development work will be carried out on the pilot scale pneumatic system. Attempts will be made to feed and convey material in "plug" form. Initial tests wil be on a short length of pipe which will be progressively increased. This system will be optimized in terms of plug lengths, air volume and pressure. The pilot scale system will be well instrumented in order to obtain data necessary to scale up to a commercial size system.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1982-83	$110,000			$110,000
1983-84	$ 36,500			$146,500
1984-85	$ 86,300			$232,800

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 457

TITLE Development of Systems to Blend Biomass and Petroleum Derived Fuels for Use in Farm Tractors

CONTRACT # 34SZ.01916-2-EL19

CONTRACTOR
Ontario Research Foundation
Centre for Alternate Fuel Utilization
Mississauga, Ontario

PRINCIPAL INVESTIGATOR A. Lawson

PROGRAM IDENTIFICATION 4.3.9.2
Biomass Materials Handling transportation & Pretreatment/ Materials Handling

DURATION April 1983 - March 1985

COST $610,000

SPONSOR Agriculture Canada

SCIENTIFIC AUTHORITY
P. Van Die
Head, Energy Section
Engineering & Statistical Research
Research Branch
Agriculture Canada
Ottawa, Ontario
K1A 0C6
Tele.: (613) 995-9671

OBJECTIVE

To design and develop fuel systems to a) emulsify ethanol/diesel fuel; b) emulsify aqueous ethanol/gasoline and c) emulsify vegetable oil/ethanol for use in farm tractors. The project includes demonstration and testing in the second year. Part b) may be a paper study.

DESCRIPTION

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1983-84	$362,000			$362,000
1984-85	$248,000			$610,000

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 175

TITLE Conversion of Pretreated Wood to Ethanol by Two Stage Hydrolysis and Fermentation Process

CONTRACT # LK229-1-4115 (DSS81-00032)
23216-3-6147 (DSS83-00027)C-181

CONTRACTOR Forintek Canada Corp.
Eastern Laboratory
800 Montreal Road
Ottawa, Ont. K1G 3Z5

PRINCIPAL INVESTIGATOR J.N. Saddler

PROGRAM IDENTIFICATION 4.3.9.4
Biomass Materials, Handling, Transportation & Pretreatment/ Pretreatment

DURATION May 1981 - March 1985

COST $301,398

SPONSOR Energy, Mines and Resources

SCIENTIFIC AUTHORITY C.R. Mackenzie
National Research Council
Rideau Falls Laboratory
Ottawa, Ontario
K1A 0R6

OBJECTIVE

To utilize pretreated wood as a growth substance for the production of cellulase enzymes. To establish an overall process which involves 1) the production of the cellulase enzyme complex 2) pretreatment of the lignocellulosic substrate 3) hydrolysis of the substrate and 4) fermentation.

DESCRIPTION

1. Screening for highly cellulolytic fungi.
2. Production of cellulases.
3. Production of pretreated wood substrates.
4. Combined hydrolysis and fermentation.
5. Inhibitor studies.
6. Establish an integrated process.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1981-82	$ 86,223			$ 86,223
1982-83	$ 97,357			$183,580
1983-84	$ 82,397			$265,977
1984-85	$ 35,421			$301,398

REPORTS

Forintek Canada Corp., "Conversion of Cellulose to Ethanol Using a Two-Stage Process," ENFOR Project C-181, 1983.

STATUS AND COMMENT

PROJECT DATA SHEET # 180

TITLE Production of Water Resistant Densified Biomass Fuel

CONTRACT # KL229-1-4120 C-214
KN107-2-4080

CONTRACTOR Pulp and Paper Research Inst.
570 St. John's Blvd.
Pointe Claire, Quebec.
H9R 3J9

PRINCIPAL INVESTIGATOR M.K. Azarniouch

PROGRAM IDENTIFICATION 4.3.9.4
Biomass Materials Handling, Transportation & Pretreatment/ Pretreatment

DURATION May 1981 - June 1984

COST $455,306

SPONSOR Energy, Mines & Resources

SCIENTIFIC AUTHORITY A.J. Dolenko
Conversion & Renewable
Energy, Mines & Resources
460 O'Connor Street
Ottawa, Ontario
K1A 0E4
Tele.: (613) 995-9447

OBJECTIVE

To evaluate experimentally the pertinent parameters of two conceptual processes of drying hog fuel, and to assess the feasibility of applying vapour recompression to these processes.

DESCRIPTION

A. The design and construction of a laboratory-scale dryer consisting of an internally heated vessel, steam generator, vapour condenser and appropriate controls and instrumentation. The vessel will be operated batchwise, and drying rates determined from the flow rates of condensed vapours.

B. Testing of the dryer, with hog fuel from different sources, to determine the drying of hog fuel as a function of:
   2. size of hog fuel praticles (including bark produced in PAPRICAN's chip debarking process)
   3. the moisture content of hog fuel.

C. Experimental system will be tested with crude tall oil as heating medium followed by determination of the hog fuel drying rates as a function of the variables in B. The degree of oil entrainment with wood and losses due to evaporation will also be measured. The pollution characteristics of the condensates will be determined on some selected samples.

D. Tests will be done to determine feasibility and product characteristics of prepared densified fuel from the product derived in C.

E. A technical and economic assessment and comparison of the two vapour recompression drying systems based on the information gained in B, C, D. A preliminary design of a continous pilot-scale dryer.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1981-82	$134,806			$134,806
1982-83	$159,200			$294,006
1983-84	$161,300			$455,306

REPORTS

SAYEGH N.N., AZARNIOUCH K., PPRIC, "Hog Fuel Drying Using Vapour Recompression (Phase I)." Pointe-Claire, Québec, ENFOR Project C-214.

AZARNIOUCH K., PPRIC, "Hog Fuel Drying Using Vapour Recompression (Phase II)", ENFOR Project C-214.

CONTINUED

STATUS AND COMMENT

PROJECT DATA SHEET # 183

TITLE To Perform A study of the pretreatment preparation of forest biomass as feedstock for bioconversion processes

CONTRACT # KL229-1-4121 (DSS83-00030)
C-222

CONTRACTOR University of Waterloo
Waterloo, Ontario
N2L 3G1

PRINCIPAL INVESTIGATOR M. Moo-Young

PROGRAM IDENTIFICATION 4.3.9.4
Biomass Materials Handling, Transportation and Pretreatment/Pretreatment

DURATION May 1981 - October 1984

COST $220,524

SPONSOR Energy, Mines and Resources

SCIENTIFIC AUTHORITY A.J. Dolenko
Conservation & Renewable Energy Branch
Energy, Mines & Resources
460 O'Connor Street
Ottawa, Ontario
K1A 0A4

OBJECTIVE

To develop and test a novel process whereby forest biomass (as wood, pulpmill sludge) is converted by chemical hydrolysis, enhanced by gamma irradiation or microwaves, into a liquid product which is suitable as feedstock for known conversion technologies in the production of industrial chemical and fuels. The aim is economic production of feedstocks.

DESCRIPTION

The project will cover two main areas of study.

1. Experimental development of the pretreatment method for optimal depolymerization, sugar yields and conversion rates. The effects of irradiation dosage, particle size and chemical strength will be examined. The prepared feedstocks will be tested in actual bioconversion processes to gain insight in its suitability.
2. Economic evaluation of the method as it compares to existing feedstock availability and other pretreatment methods for a range of conversion technologies. Computer programs will be developed for various sensitivity analyses.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1981-82	$ 58,000			$ 58,000
1982-83	$ 55,570			$113,570
1983-84	$106,954			$220,524

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 196

TITLE Pretreatment Methods for Enhancing Conversion of Lignocellulosic Material to Liquid Fuel

CONTRACT #
23216-3-6364(OSS82-00061)
23216-3-6363(OSS83-00168)
C-299

CONTRACTOR
Forintek Canada Corp.
Eastern Laboratory
800 Montreal Road
Ottawa, Ontario K1G 3Z5

PRINCIPAL INVESTIGATOR
J.N. Saddler
(613) 744-0963

PROGRAM IDENTIFICATION
4.3.9.4
Biomass Materials Handling, Transportation & Pretreatment/ Pretreatment

DURATION July 1982 - September 1984

COST $159,516

SPONSOR Energy, Mines and Resources

SCIENTIFIC AUTHORITY
R.P. Overend
National Research Council
Building R-105, Rm 135
Ottawa, Ontario
K1A 0R6
Tel.: (613) 993-1342

OBJECTIVE

To establish which component of the original wood gives rise to the principal inhibitors formed during steam treatment. To compare the rates of pentosan destruction and of pentosan solubilization.

DESCRIPTION

Methods developed in the current pretreatment will be used. Emphasis will be placed on the chemical and physical effects that pretreatment has in solubilizing the hemicellulose with as little destruction of it as possible, thereby permitting its separation and utilization, and enhancing the accessibility of the cellulose to enzymatic hydrolysis

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1982-83	$ 46,908			$ 46,908
1983-84	$ 59,518			$106,426
1984-85	$ 53,090			$159,516

REPORTS

FORINTEK Canada Corp., "Pretreatment Methods for Enhancing Conversion of Lignocellulosic Material to Liquid Fuel, ENFOR C-299", Oct., 1983.

STATUS AND COMMENT

Final report received.

84/12/06

PROJECT DATA SHEET # 215

TITLE Assessment of Wet Oxidation of Agricultural Residues to Form Fermentation Substrates

CONTRACT # 34SZ.01843-0-B103 (OSZ81-43)

CONTRACTOR
Ontario Research Foundation
Sheridan Park Research Community
Mississauga, Ontario

PRINCIPAL INVESTIGATOR Herb Robey

PROGRAM IDENTIFICATION
4.3.9.4
Biomass Materials Handling, Transportation & Pretreatment ment/Pretreatment

DURATION August 1981 - September 1983

COST $120,000

SPONSOR Agriculture Canada

SCIENTIFIC AUTHORITY
E. Manolakis
Engineering & Statistical Research Institute
Agriculture Canada
Ottawa, Ontario
K1A 0C6
Tel.: (613) 995-9671

OBJECTIVE

The overall objective of the project is to develop and test a system that converts corn stover to a fermentable substrate by using a combination of acid hydrolysis reactors and wet oxidation of residual lignin and swine manure or stover/manure mixtures. The system will produce pentose and hexose sugar streams of high theoretical yield (60% or more) that are sterile and can be fermented to fuel ethanol in particular or others such as acetone, and butanol. The system is intended to generate most of its own requirements for acid, energy (steam), and essential nutrients for fermentation.

DESCRIPTION

Phase 1 (The Hydrolysis System)
The contractor will perform preliminary investigations of a "hydrolysis system" using separate reactors for acetic acid and steam hydrolysis of corn stover which will yield pentose and hexose sugar streams. Lignin residue from the cellulose hydrolysis reactor will be wet oxidized using the WETOX reactor to optimize steam and acetic acid production, reaction kinetics and process conditions relative to the requirements of the hemicellulose and cellulose hydrolysis reactors. The experiments will be carried out in a batch/bench scale configuration where system integration is simulated only. For each promising sugar stream produced in the experiments, studies to ensure that the sugar streams are fermentable will be conducted at the flask scale (anaerobically, where practical). (Note: Fermentability studies refer primarily to hexose sugar streams). Preliminary investigations only of fermenting pentose sugar streams to fuel ethanol will be conducted.

Phase 2 (The Manure Treatment System)
The contractor will perform basic research studies on: 1) wet oxidation of swine manure to supply nutrients (for fermentation) and/or steam and acid; 2) wet oxidation of manure/lignin mixtures to supply nutrients and/or steam and/or acid and; 3) oxidative hydrolysis of stover/manure mixtures to supply nutrients, steam, acid and/or fermentable carbohydrates. Products from these experiments (e.g. steam, acid, nutrients, fermentable carbohydrates) will be studied with respect to fermentability in experiments using sugar streams produced in Phase 1 experiments and or products derived solely from wet oxidation of manure or stover/manure mixtures.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1981-82 1982-83 1983-84	$25,000 $80,000 $15,000			$ 25,000 $105,000 $120,000

REPORTS

CONTINUED

STATUS AND COMMENT

83/04/26

PROJECT DATA SHEET # 234		**PROGRAM IDENTIFICATION**	4.3.9.4 Biomass Materials Handling, Transportation & Pretreatment/ Pretreatment
TITLE	Microbial Fractionation of Native Biomass to Lignin, Cellulose and Hemicellulose	**DURATION**	November 1981 - November 1984
CONTRACT #	Strategic Grant	**COST**	$87,000
CONTRACTOR	Queen's University Department of Chemical Engineering Kingston, Ontario K7L 3N6	**SPONSOR**	Natural Sciences and Engineering Research Council
PRINCIPAL INVESTIGATOR	D.H. Bone		

OBJECTIVE

To develop a fermentation process which will convert wood, bark, straw and other native lignocellulosics (LC) into free lignin, cellulose and hemicellulose using lignolytic fungi. Lignin will be further processed into aromatics and phenols by microbes. Cellulose and hemicellulose will be available in an easily utilizable form for conversion to sugars, which can then be used as a substrate for the production of liquid fuels (e.g. ethanol). Two bioreactors will be used: a recirculating tower bioreactor and a fluidized bed reactor. The microbial conversion of LC to lignin and polysaccharides will be optimized for minimum energy use and economics.

DESCRIPTION

1. Using white-rot fungi to break open the lignin-cellulose-hemicellulose complex with minimal degradation of the polysaccharides, and to utilize a range of native LC including woodchips, bark and straw.
2. To compare two reactor systems (a) continuously fed fluidized bed reactor (FBR) (b) recirculating tower bioreactor (RTB).
3. To optimize these two reactors for efficient production of free lignin, cellulose and hemicellulose for their further conversion to liquid fuels and chemicals.
4. To select strains of microbes which will be able to co-metabolize lignin to aromatics and phenols.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1981-82	$38,000			$38,000
1982-83	$24,000			$62,000
1983-84	$25,000			$87,000

REPORTS

STATUS AND COMMENT

Working in collaboration with A.J. Daugulis. 84/12/04

PROJECT DATA SHEET # 238

TITLE Saccharification of Biomass by Reduced Pressure Pyrolysis Followed by Hydrolysis

CONTRACT # Strategic Grant

CONTRACTOR University of Sherbrooke
Engineering Dept.
Sherbrooke Quebec

PRINCIPAL INVESTIGATOR C. Roy

PROGRAM IDENTIFICATION 4.3.9.4
Biomass Material Handling, Transportation & Pretreatment/ Pre-treatment

DURATION November 1981 - November 1984

COST $159,633

SPONSOR Natural Sciences and Engineering Research Council

OBJECTIVE

To undertake pyrolytic saccharification of wood for the production of ethanol. U.S. studies on pure cellulose have indicated that pyrolysis under reduced pressure produces material that is readily hydrolyzable. It is proposed to investigate the conversion of different lignocellulosics.

DESCRIPTION

The overall approach will be the pyrolytic conversion of different lignocellulosics under reduced pressure. The pyroligneous material will at the same time be characterized and acid hydrolysed to determine its suitability as a feedstock for ethanol production.
Short Term: To produce samples of pyroligneous material from diverse lignocellulosics (hardwood, soft wood, wheat straw, oat straw, corn stover, bark) in order to treat them by acid hydrolysis (batch). Catalysts will be tested to increase yields or to suitably modify the pyroligneous
To develop analytical techniques for the identification and quantification of the sugars.
material.
Long Term: If the batch hydrolysis tests prove promising further development will be undertaken. To determine the fermentability of the hydrolysate and to investigate any microbial inhibitors in the hydrolysate. If inhibitors are present the sugars would be isolated or purified. Preliminary fermentation would be carried out by either conventional yeast or by bacteria adapted to pentoses and hexoses.

FUNDING

FISCAL YEAR	SPONSOR	EQUIPMENT		CUMULATIVE TOTAL
1981-82	$36,000	$ 8,500		$ 44,500
1982-83	$40,356	$32,000		$116,856
1983-84	$42,777			$159,633

REPORTS

ROY C., LALANCETTE A., DE CAUMIA B., BROUILLARD D., RIVARD P., and CÔTÉ B., "Production of oils oils and chemicals by vacuum pyrolysis of wood," 34th Canadian Chemical Engineering Conference, Québec, Qu. September 30 - October 3, 1984.

ROY C., LALANCETTE A., DE CAUMIA B., BLANCHETTE D., CÔTÉ B., RENAUD M., and RIVARD P., "The Vacuum Pyrolysis of Biomass as a Process for the Production of Chemicals and Oils," Bioenergy 1984, Gothenburg, Sweden. June 18-21, 1984

MÉNARD H., GRISÉ M., MARTEL A., ROY C., and BÉLANGER D., "Saccharification de la biomass par pyrolyse pression réduite suivie d'une hydrolyse," Comptes-Rendu du Cinquième Séminaire R&D Bioénergtique, Ottawa, Ontario, 26-28 mars 1984.

MÉNARD H., BÉLANGER D., CHAUVETTE G., GABOURY A., KHORAMI L.J., GRISÉ M., MARTEL A., POTVIN E., ROY C., LANGLOIS R., "Caractérisation des jus pyrolytiques en provenance de différents procédés de conversion du bois," Compte-Rendus du Cinquième Séminaire R&D Bioénergtique, Ottawa, Ontario 26-28, 1984

CONTINUED

STATUS AND COMMENT

Working in collaboration with A. Leduy 84/12/01

PROJECT DATA SHEET # 241

TITLE Evaluation of a One Stage Continuous Acid Hydrolysis Process for Conversion of Agricultural Materials into Sugars

CONTRACT # 01843-1-EL04 (0SZ81-00098)

CONTRACTOR
Stake Technology Ltd.
220 Wyecroft Road
Oakville, Ontario
L6K 3V1

PROGRAM IDENTIFICATION 4.3.9.4 Biomass Materials Handling, Transportation & Pretreatment/ Pretreatment

DURATION November 1981 - March 1984

COST $66,314

SPONSOR Agriculture Canada (Liquid Fuels Task)

SCIENTIFIC AUTHORITY
E. Manolakis
Engineering & Statistical Research Institute
Building 94
Agriculture Canada
Ottawa, Ontario
K1A 0C6

OBJECTIVE

The overall objective of the project is to perform exploratory tests on the patented Stake Technology autohydrolysis reactor using combined steam treatment and a hydrogen ion source such as the infusion of SO2 on a variety of agricultural materials. Tested for each combination of residence time, temperature and hydrogen ion concentration and process configuration (i.e. single pass or double pass, etc.) the production of fermentable sugar is to be optimized for the production of fuel ethanol. The exploratory nature of the project is to test the above concept so that a decision can be made regarding carry-on studies to establish a detailed technical and economic model.

DESCRIPTION

The contractor will perform preliminary experiments on a batch/bench scale autohydrolysis reactor (approx. 50 g samples) to determine optimum reaction kinetics and process conditions using steam treatment and a hydrogen ion source (e.g. infusion of SO gas or others) for the maximum or optimum conversion of designated feedstocks to fermentable monosaccharides without subsequent enzyme hydrolysis. Designated feedstocks are to include corn grain, corn stover alone, corn cobs, barley grain and barley straw. Sugars from the liquid stream only will be analyzed qualitatively and quantitatively to determine optimum and maximum production of fermentable sugar relative to process conditions and flow configuration. Fermentability studies will be conducted on promising sugar hydrolysates (Note: Fermentability studies refer to preliminary investigations only in a flask or test tube scale to determine if the sugar streams are fermentable (anaerobically, if practical)). The contractor will observe the impact of autohydrolysis on potential protein and oil recovery/degradation on corn and barley grain feedstocks.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1981-82	$12,814			$12,814
1982-83	$43,500			$56,314
1983-84	$10,000			$66,314

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 320

TITLE Use of Extrusion in the Conversion of Agricultural Biomass to Fuel Alcohol

CONTRACT # 01916-2-EL17 (15Z82-00058)

CONTRACTOR
Weston Research Centre
1047 Yonge Street
Toronto, Ontario
M4W 2L3

PRINCIPAL INVESTIGATOR
R. Edamura
Tel.: (416) 922-5100

PROGRAM IDENTIFICATION
4.3.9.4
Biomass Materials Handling, Transportation & Pretreatment/ Pretreatment

DURATION July 1982 - August 1983

COST $86,000

SPONSOR
Agriculture Canada
(Liquid Fuels Task)

SCIENTIFIC AUTHORITY
E. Manolakis
Engineering & Statistical Research Institute
Research Branch
Agriculture Canada
Ottawa, Ontario K1A 0C6
Tel.: (613) 995-9671

OBJECTIVE

To develop and assess the economic feasibility of the 2-stage extruder process, combined with microbial fermentation, for the rapid conversion of agricultural biomass to fuel grade ethanol.

DESCRIPTION

1. To hydrolyse agricultural feedstocks (corn stover, wheat straw, alfalfa) to fermentable sugars using a two stage extrusion process. The proces will be optimized for maximum production of pentose and hexose sugars. Extruded material from each stage will be analytically monitored for moisture, lignin, sugar content (yield and concentration) and ash. Extruded material from the first stage will be monitored for enzyme and acid digestibility. Operating parameters to be varied in each stage will include temperature, pressure, residence time and catalyst concentration.
2. To assess the fermentability of selected samples from the process streams of each stage.
3. To determine the energy inputs and mass balances of the most promising process configurations and compare to other methods of pretreatment/hydrolysis such as steam explosion, ball milling, acid and enzyme hydrolysis.
4. To perform an economic prefeasibility evaluation of the use of extrusion to pretreat/hydrolyse the agricultural feedstocks tested.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1982-83 1983-84	$68,000 $18,000			$68,000 $86,000

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET #	327	**PROGRAM IDENTIFICATION**	4.3.9.4 Biomass Materials Handling, Transportation & Pretreatment/ Pretreatment
TITLE	Biomass Feedstocks from Poplar Wood using Supercritical Fluids		
CONTRACT #	KN107-2-4110 (DSS82-00026) C-295	**DURATION**	May 1982 - May 1984
		COST	$83,072
CONTRACTOR	B.C. Research 3650 Wesbrook Mall Vancouver, B.C. V6S 2L2	**SPONSOR**	Energy, Mines & Resources
		SCIENTIFIC AUTHORITY	A.J. Dolenko Conservation & Renewable Energy, Mines & Resources 460 O'Connor Street Ottawa, Ontario K1A 0E4 Tele.: (613) 995-9447
PRINCIPAL INVESTIGATOR	E. McDonald John Howard Tel.: (604) 224-4331		

OBJECTIVE

To enhance the digestibility of wood for ruminant animals by using supercritical fluids to modify cell walls and disrupt cellulose-lignin bonds.

DESCRIPTION

Poplar will be treated with supercritical fluids including carbon dioxide and possibly ammonia. Pressures in the treatment chamber will be changed rapidly to cause maximum disruption to chemical bonds and the physical structure of wood. Test will be run on the treated wood to determine digestibility improvements. An economic assessment will be made of the process developed.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1982-83	$77,464			$77,464
1983-84	$ 5,608			$83,072

REPORTS

B.C. Research, "Biomass Feedstocks from Poplar Wood Using Super Critical Fluids." ENFOR Project C-295, 1983.

STATUS AND COMMENT

PROJECT DATA SHEET #	347	**PROGRAM IDENTIFICATION**	4.3.9.4 Biomass Materials Handling, Transportation & Pretreatment/ Pretreatment
TITLE	Preparation of Wood for Combustion		
CONTRACT #	CEA G297	**DURATION**	July 1982 - May 1983
CONTRACTOR	Sandwell Suite 601 1550 Alberni Street Vancouver, B.C. V6G 1A4	**COST**	$50,980
		SPONSOR	Canadian Electrical Association
PRINCIPAL INVESTIGATOR	Colin MacCallum		

OBJECTIVE

The CEA requested Sandwell to study the use of wood particles as fuel in conventional utility boilers, for the production of electricity. In the first part of the study, consideration was given to the possible advantages of prior separation of the wood into lignin and wood fibre. After a thorough assessment, there did not appear to be any incentive for separating the lignin and wood fibre. At a meeting with the CEA technical advisors, it was agreed that the remainder of the project would focus on factors pertinent to the preparation of wood for combustion in conventional utility boilers.

DESCRIPTION

1. When outstanding information is obtained from suppliers, complete the report sections on (a) the review of equipment for size reduction of wood, (b) the effect of particle size and moisture content on burnout time and (c) the effect of wood co-firing on the emission of SO and SO from the combustion of fossil fuels.
2. Prepare a draft report section on the drying of wood waste.
3. Assess the optimum feed for various existing conventional utility boilers. Superficially, it appears that pulverized firing would be the only feasible alternative.
4. Review the burner requirements for firing pulverized hog fuel.
5. Develop capital and operating costs for systems to prepare wood fuel for feasible firing methods.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1982-83	$ 50,980			$ 50,980

REPORTS

STATUS AND COMMENT

Since it is not attractive to separate lignin from wood fibre prior to combustion, the balance of the project is focussing on the technical factors and associated economics of preparing wood for combustion in conventional utility boilers. Although we are waiting for some supplementary information, report sections have been prepared on (a) the review of equipment for size reduction of wood, (b) the effect of particle size and moisture content on combustion characteristics and (c) the effect of wood co-firing on the emission of SO and SO from the combustion of fossil fuels. After other appropriate technical factors have been addressed and the feasible firing methods have been identified, capital and operating costs for systems to prepare wood fuel will be developed. Final report is in preparation.

84/12/07

PROJECT DATA SHEET # 363

TITLE
Ethanol from Municipal Waste
Cellulose Pretreatment
Optimization

CONTRACT #
31926-3-0050 (05X83-00031)

CONTRACTOR
W.L. Wardrop & Assoc. Ltd.
77 Main Street
Winnipeg, Manitoba
R3C 3H1

PRINCIPAL INVESTIGATOR
H. Husain
Tele.: (204) 956-0980

PROGRAM IDENTIFICATION
4.3.9.4
Biomass Materials Handling,
transportation & pretreatment

DURATION
June 1983 - January 1984

COST
$28,775

SPONSOR
Bioenergy Program
National Research Council

SCIENTIFIC AUTHORITY
L van den Berg
National Research Council
Biological Sciences
Ottawa, Ontario
K1A OR6
Tele.: (613) 992-3310

OBJECTIVE

To determine the effect of high temperature pretreatment on newsprint in making it more susceptible to enzymatic attack.

DESCRIPTION

1. Determine optimum pretreatment conditions for newsprint by varying the following:
   (a) heating temperature and time
   (b) presoaking, grinding and other pretreatments
   (c) solids concentration
   (d) pH
   (e) catalysts
2. Report on data analysis and economic analyses.
   The work shall be performed in accordance with the technical portion of the contractor's proposal of February 1983, entitled "Ethanol from Minicipal Solid Waste Cellulose Pretreatment Optimization".

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$28,775			$28,775

REPORTS

W.L. Wardrop & Associates Ltd., "Ethanol From Municipal Solid Waste Cellulose Pretreatment optimization," Final Report submitted to National Research Council, March 1984

STATUS AND COMMENT

Results of this completed study indicated that steam treatment of newsprint did not appear a practical way to improve their enzymatic degradability.

84/12/06

PROJECT DATA SHEET # 374

TITLE Dewatering and Feeder Design Parameters

CONTRACT # 31926-3-5022 (DSX83-00089)

CONTRACTOR
Stake Technology Ltd.
220 Wyecroft Road
Oakville, Ontario
L6K 3V1

PRINCIPAL INVESTIGATOR
D.B. Brown
J.D. Taylor

PROGRAM IDENTIFICATION
4.3.9.4
Biomass Materials Handlings
Transportation and Pretreatment/
Pretreatment

DURATION August 1983 - January 1984

COST $58,132

SPONSOR
Bioenergy Program
National Research Council

SCIENTIFIC AUTHORITY
R.P. Overend
Division of Energy
National Research Council
Canada
Building R-105 Rm 135
Ottawa, Ontario
K1A OR6
Tele: (613) 993-1342

OBJECTIVE

To design, construct and test dewatering press with ability to apply static pressure and high frequency mechanical pulse on sample of biomass to be dewatered.

DESCRIPTION

1) Undertake literature search on mechanical dewatering. Consult with manufacturers of mechanical dewatering presses. Rewiew and summarize present knowledges and practices of mechanical dewatering.
2) Design and build laboratory press capable of applying adjustable static pressure and high pressure mechanical pulse.
3) Generate fundamental data for hydrostatic water expulsion from poplar/aspen chips by measuring water removal relative to specific pressures applied during constant time at pressure.
4) Repeat test as in 3) with introducing mechanical pulse on compressed smaple of various frequencies.
5) Repeat tests as in 4) with elevated temperatures of chip sample.
6) Proceed with full microscopic examination of fibres obtained in previous tests.
7) Determine pressate liquid characteristics: B.O.D. Level, dissolvent solids, suspended solids, dissolved carbon on selected test runs.
8) Summarize results and determine effects of:
   a) high pressure mechanical pulse on level of dewatering
   b) elevated temperature of biomass sample on level of dewatering
   c) mechanical pulse and static pressure on fibre structure
9) Provide summary of energy and mass balance around the dewatering step.
10) Compare and discuss:
    a) Energy consumption of the different press processes
    b) Final products of pressing process
11) Summarize recommendation for future work with equipment development, as well as evaluation of the other feedstocks such as bark, peat, wood residue, etc., of different humification.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$58,132			$58,132

REPORTS

Final report on file with NRC Division of Energy

CONTINUED

STATUS AND COMMENT

Analysis of the data is still underway.

84/12/06

PROJECT DATA SHEET # 375

TITLE
Study of the Grinding of Wood Chips and Bark to Fine Powders

CONTRACT #
23216-3-6146 (0SU83-00007)
C-433

CONTRACTOR
University of Toronto
Simcoe Hall, Room 1335
Toronto, Ontario
M5S 1A1

PRINCIPAL INVESTIGATOR
O. Trass

PROGRAM IDENTIFICATION
4.3.9.4
Biomass Materials Handling
Transportation and Pretreatment/
Pretreatment

DURATION
April 1983 - March 1984

COST
$12.084

SPONSOR
Energy, Mines & Resources

SCIENTIFIC AUTHORITY
A.J. Dolenko
Renewable Energy Division
Energy, Mines & Resources
460 O'Connor Street
Ottawa, Ontario
K1A 0E4
Tele.: (613) 995-9447

OBJECTIVE

To establish the grinding performance of the novel Szego mill for grinding wood chips and bark to fine particle sizes.
The main feed variables are moisture level, and type of wood or bark. The important operating variables are the rate of feed, the rotational speed and the number of passes through the mill. Some mill design changes may also be studied.
The results should give mill capacity, particle size and specific energy consumption for each set of conditions.

DESCRIPTION

The novel Szego mill has proven its value as an efficient and versatile grinding mill for both dry and wet grinding operations. It consists principally of a stationary, cylindrical grinding surface inside which a number of helically grooved rollers rotate, being suspended by flexible wire rope shafts from flanges connected to a central drive shaft. The feed material enters at the top and the product is discharged at the bottom of the mill. The particles, upon entering the grinding unit are repeatedly crushed between the rollers and the stationary grinding surface. The crushing force is created mainly by the radial acceleration of the rollers. An important feature is the ability of the roller grooves to aid transport of the material through the mill, thus providing a means to control residence time and mill capacity. The mill has been patented.
A major study on grinding coal for the preparation of coal-slurry fuels has been undertaken and the mill has shown itself to be very cost effective, with high capacity and modest power consumption compared to other, commercially available grinding mills.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$12.084			$12.084

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 396

TITLE
The Solubilisation of
Lignocellulosic Residues
Using Ultrasonic Waves

CONTRACT # 31926-3-0051 (OSX83-00151)

CONTRACTOR
Centre de recherche
industrielle du Québec
333, rue Franquet
Ste-Foy, Québec
G1V 4C7

PRINCIPAL INVESTIGATOR D.A. Gosselin

PROGRAM IDENTIFICATION
4.3.9.4
Biomass Materials Handling,
Transportation & Pretreatment/
Pretreatment

DURATION November 1983 - June 1984

COST $18,064

SPONSOR
Bioenergy Program
National Research Council

SCIENTIFIC AUTHORITY
S. Hasnain
National Research Council
Division of Energy
Building R-105, Room 138
Ottawa, Ontario
K1A 0R6
Tele.: (613) 993-1342

OBJECTIVE

To do a comprehensive literature review of ultrasound science and the technology and to assess its potential as a pretreatment method for lignocellulosic substrates for the production of fuels, chemicals, fiber and fodder.

DESCRIPTION

This is a preliminary assessment of the use of ultrasonic waves for the solubilisation of cellulose and hemicellulose in emulsions of agricultural residues. This study will be composed of the following:

(1) General review of the applications of ultrasonic technology.
(2) Identification of manufacturers of and costs associated with the fabrication of lab and industrial-scale ultrasonic generators.
(3) Literature review of work carried out on the breakdown of lignocellulosics using ultrasonic waves.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$18,064			$18,064

REPORTS

Draft report submitted.

STATUS AND COMMENT

Preliminary assessment suggests the process is not an economically acceptable pretreatment.

PROJECT DATA SHEET #	416	**PROGRAM IDENTIFICATION**	4.3.9.4 Biomass Materials Handling, Transportation & Pretreatment/ Pretreatment
TITLE	Sequential Depolymerization of Lignocellulosics. Establishment of a Pretreatment Method Based on Shear Degradation of Polymers	**DURATION**	November 1983 - November 1986
		COST	$202,200
CONTRACT #	Strategic Grant	**SPONSOR**	Natural Sciences and Engineering Research Council
CONTRACTOR	University of Sherbrooke Dept. Chemical Engineering Sherbrooke Quebec J1K 2R1		
PRINCIPAL INVESTIGATOR	E. Chornet		

OBJECTIVE

1. The fractionation of lignocellulosics into its major components by rapid passage through orifices.
2. The development of a process capable of pumping wood slurries (20% solids).
3. The autohydrolysis of the hemicellulose fraction during the fractionation process.
4. The dissolution of the "lignin" fraction using solvents derived from lignocellulosics.
5. Acid hydrolysis of the cellulosic fraction in conjunction with a plug flow reactor where a high shear aids the depolymerization.
6. Mass and energy balances as well as the detailed characterization of the products using various techniques.

DESCRIPTION

This approach combines the simplicity of simple pumping through a tubular reactor to cause a degradation action resulting from shear forces inside the reactor as well as a shear force resulting from a sudden discharge through an orifice. The shear action is enhanced by an explosive discharge resulting from the rapid decompression through the orifice. The ultrasonic waves are generated by this discharge aid in the breakdown of the smaller particles present in the solution.

The polymer breakdown has been well documented in the plastics industry and its extension to macromolecules has resulted in two new Canadian technologies

- MULTIVICS: Starch dextrans
- PLASTISTARCH: Starch Sugars

This work hopes to extend these concepts to the degradation of lignocellulosics by taking advantage of three important points.

- lignocellulosics are a mixture of three types of polymers (hemicellulose, cellulose and lignin)
- each of the polymers has a different glass point in different temperature ranges.
- by the careful choice of the temperature, mechanical system and of the solvent it is possible to conceive of a concurrent fractionation and depolymerization.
- the depolymerizing process requires simple acids for the cellulose and a solvolysis for the lignin.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1983-84	$68,400			$ 68,400
1984-85	$67,400			$135,800
1985-86	$66,400			$202,200

REPORTS

CONTINUED

STATUS AND COMMENT

PROJECT DATA SHEET # 421

TITLE A Study of a Separator-Shear System for the Processing of Biomass (Part of the ENFOR Program)

CONTRACT # KH603-3-0023(OSB83-00163)
P-250

CONTRACTOR Forest Engineering Research Institute of Canada
143 Place Frontenac
Pointe-Clair, Quebec
H9R 4Z7

PRINCIPAL INVESTIGATOR A.W.J. Sinclair

PROGRAM IDENTIFICATION 4.3.9.4
Biomass Materials Handling Transportation & Pretreatment/ Pretreatment

DURATION June 1983 - March 1984

COST $216,399

SPONSOR Environment Canada

SCIENTIFIC AUTHORITY G.H. Manning
Pacific Forest Research Centre
Canadian Forest Service
506 West Burnside Road
Victoria, British Columbia
V8Z 1M5
Tele. (604) 388-3811

OBJECTIVE

1. To incorporate the Nicolson biomass shear (the concept of which is proven) into a reliable, preproduction prototype of a complete stationary system, and to establish production capacity and processing costs.
2. To process log sortyard and logging debris into a cleaner, more homogeneous product suitable as feedstock for hogged fuel without modification to the hog mill installation.
3. To report the costs, productivities and energy balance of the stationary-shear system.
4. To develop a system for the industry that will be commercially available in 1984 to reduce petroleum purchases.

DESCRIPTION

1. Incorporate existing Nicholson shear into a reliable total system using the experience gained from previous tests and the engineering drawings of the precommercial prototype of the Nicholson shear.
2. Set up the separator-shear system in a log sortyard of a cooperating forest products company.
3. Process sortyard debris.
4. Use detailed timing and shift-level measuring techniques to determine system productivity and capacity. Analyze sortyard debris and processed material to establish change in physical characteristics (size distribution, ash and moisture content). Measure energy requirements of separator-shear system. Weigh material into and out of the system.
5. Transport processed material to a hog mill for hogging and waste material to a landfill site for disposal. Determine productivity, costs and energy requirements. Analyze hogged fuel to determine physical characteristics.
6. Publish report on productivity, costs, energy efficiency, and processing performance of the system.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$216,399			$216,399

REPORTS

Final report received May 1984

CONTINUED

STATUS AND COMMENT

Project P-250 completed

PROJECT DATA SHEET # 448

TITLE A Study of Logging Residue Processing Systems

CONTRACT # KH603-3-0404(OSB83-00195)
P-291

CONTRACTOR Philip Oakley & Associates
400 - 905 West Pender Street
Vancouver, British Columbia
V6C 1L6

PROGRAM IDENTIFICATION 4.3.9.4
Biomass Materials Handling
Transportation & PreTreatment/
PreTreatment

DURATION June 1983 - October 1983

COST $9,125

SPONSOR Environment Canada

SCIENTIFIC AUTHORITY G.H. Manning
Pacific Forest Research
Centre
Canadian Forest Service
506 West Burnside Road
Victoria, British Columbia
V8Z 1M5
Tele.: (604) 388-3811

OBJECTIVE

DESCRIPTION

To review, rework and standardize the information contained in the reports "Further Development of Logging Residue Processing Systems (Forestal) and The Harvesting and Processing of Residual Biomass in the British Columbia interior wet Belt (ECFS) into a single report. In addition, relevant information contained in other reports, such as, A Trial of a Separator and Shear System for Processing Sortyard Debris for Hogged Fuel and Pulp Chips" (FERIC TR-51) together with unpublished information available within the forest industry will be included in the report. Emphasis will be placed on the concept, development and costs of the shear system. Conclusion will be drawn as to where and when the system may be used to best advantage.

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$9,125			$9,125

REPORTS

MANNING G.H., and OAKLEY P. "An analysis of two trials of a portable shear-type residue processing system," information report BC-X-249

STATUS AND COMMENT

Completed

84/12/06

PROJECT DATA SHEET # 455

TITLE Field testing of the experimental prototype of the RollSplitter

CONTRACT # KH405-3-0417
P-297

CONTRACTOR Great Lakes Forest Research Centre
Environment Canada
Sault Ste. Marie, Ontario
P6A 5M7

PROGRAM IDENTIFICATION 4.3.9.4
Biomass Materials Handling
Transportation & PreTreatment/
PreTreatment

DURATION April 1983 - March 1985

COST $49,710

SPONSOR Environment Canada

SCIENTIFIC AUTHORITY B.J. Sutherland
Great Lakes Forest
Research Centre
Canadian Forestry Service
P.O. Box 490
Sault Ste. Marie, Ontario
P6A 5M7
Tele.: (705) 949-9461

OBJECTIVE

1. To field test the Roll Splitter in warm weather conditions to determine the operating specifications and productivity levels.
2. To quantify the dewatering ability of the Roll Splitter and the drying rate of the resulting splinters or processed woody material.
3. To make a full assessment of the existing prototype using two pairs of rolls in series.

DESCRIPTION

Phase I

To field test the experimental prototype roll splitter with various sizes of woody material. All operating components are hydraulically operated using variable displacement pumps which can be load or pressure compensated, thus the drive system is flexible over a wide range of operating conditions. Parameters such as torque, roll speed, power and crushing force are to be measured and operating specifications established for the roll splitter. During tests the dewatering ability of the process will be measured by gathering the water squeezed out of samples of known moisture content and weight.

Phase II

To conduct data analysis of all test results collected in Phase I. This will include the establishing of operating specifications that would maximize performance of the roll splitter under various conditions. The specifications established will be of sufficient detail and completeness to enable design of a preproduction prototype machine.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1983-84 1984-85	$11,555 $38,155			$11,555 $49,710

REPORTS

STATUS AND COMMENT

A final report on test results is expected by December 28, 1984

84/12/06

PROJECT DATA SHEET # 464

TITLE Assessment of Agricultural Residues as Substrates for Cellulase Production and Hydrolysis

CONTRACT # E2136 EL30

CONTRACTOR
Forintek Canada Corp.
800 Montreal Road
Ottawa, Ontario
K1G 3Z5

PRINCIPAL INVESTIGATOR J.N. Saddler

PROGRAM IDENTIFICATION 4.3.9.4
Biomass Materials Handling, Transportation & Pretreatment/ Pretreatment

DURATION April 1983 - March 1985

COST $46,000

SPONSOR Agriculture Canada

SCIENTIFIC AUTHORITY
E. Manolakis
Engeering & Statistical Research Branch
Agriculture Canada
Engeering Bldg 94
C.E. Farm
Ottawa, Ontario
K1A 0C6
Tele.: (613) 995-9671

OBJECTIVE

1. To screen and test a variety of agricultural materials that may or may not have already been pretreated by solvent extraction, steam explosion, silaging, etc. as to their facility as substrates for cellulase production and hydrolysis.
2. Fundamental studies of cellulase system s.a. irreversible adsorption to substrate, enzyme half-life, inhibition by accumulated products, alcohol inactivation.

DESCRIPTION

1. Provide a service to the ERDAF program by meeting objective 1 on substrates designated by the S.A. that will complement other ERDAF contractors' work and will serve as a quick screen to other substrates not currently under investigation such as sunflower hulls, wheat chaff, refuse screenings, etc.
2. Basic studies of comparing filter paper and carboxymethyl cellulose activity etc vs. actual activity of the enzyme complex to hydrolyse natural cellulosic substrates to glucose; irreversible adsorption of enzyme to the substrate etc.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1983-84 1984-85	$ 9,000 $37,000			$ 9,000 $46,000

REPORTS

STATUS AND COMMENT

PROJECT DATA SHEET # 465		**PROGRAM IDENTIFICATION**	4.3.9.4 Biomass Materials Handling, Transportation & PreTreatment/ PreTreatment
TITLE	Optimization and Testing of Technology to Hydrolyse Jerusalem Artichoke Tubers to Fermentable Sugars	**DURATION**	April 1983 - March 1985
CONTRACT #	01916-3-EL25(0SZ83-00078)	**COST**	$26,690
CONTRACTOR	St. Lawrence Technologies Ltd. 50 Elmwood Avenue South Mississauga, Ontario L5G 3J7	**SPONSOR**	Agriculture Canada
PRINCIPAL INVESTIGATOR	P. Assarsson	**SCIENTIFIC AUTHORITY**	E. Manolakis Engeering & Statistical Research Branch Agriculture Canada Engeering Bldg #94 C.E. Farm Ottawa, Ontario K1A 0C6 Tele.: (613) 995-9671

OBJECTIVE

1. To optimize the technology to hydrolyse Jerusalem Artichoke tubers (insulin) to fermentable sugars (fructose and glucose) using the St. Lawrence Technologies (SLT) pilot scale plug flow reactor.
2. To further analyse the sugars in these hydrolysates and test them for their fermentability to ethanol.
3. To evaluate the economy of the SLT processing system as applied to Jerusalem Artichokes.
4. To evaluate the possibilty of farm-scale and community scale use of the SLT system for hydrolysis of Jerusalem artichokes.

DESCRIPTION

1. Jerusalem Artichoke tubers will be cut or ground and slurried in water containing acid catalyst. The highest possible consistency which can be pumped through the reactor will be determined and used. A series of runs through the SLT reactor will be made to determine optimal operating conditions.
2. Hydrolysate solution will be analysed in the SLT analytical facility to determine the type and quantity of the various sugars present, including dimers and trimers.
3. Hydrolysate obtained (under optimum processing conditions) will be tested for fermentability by ordinary yeast. The fermentations will be carried out in shake flask tests and in the SLT 250 gallon fermentor. The alcohol yield and quality in the fermentation batch will be determined by analytical methods.
4. Energy inputs and mass balances of the system will be determined as the data is gathered.
5. An economic analysis of the SLT system will be performed and the possibility of on-farm and community scale use of the SLT system for hydrolysis of Jerusalem artichoke tubers for alcohol production will be evaluated.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1983-84	$ 8,690			$ 8,690
1984-85	$18,000			$26,690

REPORTS

CONTINUED

STATUS AND COMMENT

Work completed. Draft report under revision prior to delivery.

84/12/05

PROJECT DATA SHEET # 483

TITLE Research work on the Mechanism and Application of Enzymatic Hydrolysis of Wood to Glucose: The Nature and Components of Cellulose Complexes, Their Enzymology and Molecular Biology

CONTRACT # 5455.KN107-3-4534(05583-00178)

CONTRACTOR
Forintek Canada Corp.
Eastern Laboratory
800 Montreal Road
Ottawa, Ontario
K1G 325

PROGRAM IDENTIFICATION 4.3.9.4
Biomass Materials Handling, Transportation & Pretreatment/ Pretreatment

DURATION February 1984 - March 1985

COST $156,000

SPONSOR Environment Canada

SCIENTIFIC AUTHORITY
P. Singh
Canadian Forestry, Service
Environment Canada
19th floor
Place Vincent Massey
Hull, Quebec
K1A 1G5
Tele.: (819) 997-3350

OBJECTIVE

1. To produce, concentrate and store enzyme broths with enhanced hydrolytic activity towards lignocellulosics through fundamental research into the mechanisms of cellulose production in highly cellulolytic fungi. The research will also consider synergism of enzyme components, substrate concentration, physical barriers, reversible and irreversible enzyme adsorption on substrates and half-lives of enzyme components as factors of conversion efficiency. Similar studies will be conducted on xylanase for the purpose of degrading hemicellulose constituents.
2. To provide a technical assessment of the different parameters necessary to produce, concentrate, store and use the extracellular enzymes produced by highly cellulolytic fungi which are needed for the conversion of lignocellulosics to sugars.
3. To initiate a mutation program to further increase the hydrolytic activity of high cellulase producing strains already identified. The cellulase enzyme complexes of these different strains will be compared to identify the optimum "synergist mixture" that will give the greatest hydrolysis.

DESCRIPTION

The work shall be conducted in accordance with your proposal to the Canadian Forestry, Service, dated July, 1983

FUNDING

FISCAL YEAR	SPONSOR			CUMULATIVE TOTAL
1983-84	$156,000			$156,000

REPORTS

STATUS AND COMMENT

84/12/06

BIOENERGY PROJECT MANAGEMENT

PROJECT DATA SHEET # 102

TITLE Maintenance of an Awareness of Forest Biomass Technology Developments and ENFOR Project Assessments

CONTRACT # 23216-3-6139 (DSS83-00011) E-1

CONTRACTOR
Forintek Canada Corp.
Eastern Laboratory
800 Montreal Road
Ottawa, Ontario
K1G 3Z5

PRINCIPAL INVESTIGATOR
J. Shields
(613) 744-0963

PROGRAM IDENTIFICATION
4.3.10
Bioenergy Project Management

DURATION April 1979 - June 1984

COST $960,109

SPONSOR Energy, Mines and Resources

SCIENTIFIC AUTHORITY
A. Dolenko
Renewable Energy Division
Energy, Mines and Resources
460 O'Connor Street
Ottawa, Ontario
K1A 5H3

OBJECTIVE

1. To maintain current awareness of biomass energy technology developments with specific reference to needs and activities of the forest industry in Canada.
2. To coordinate, administer and/or manage ENFOR projects, where appropriate.

DESCRIPTION

Maintain two man-years devoted to biomass energy activity in western and eastern Canada to the extent that the expertise necessary to support the above objectives is sustained.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1979-80	$150,000			$150,000
1980-81	$159,330			$309,330
1981-82	$225,505			$534,835
1982-83	$222,900			$757,735
1983-84	$170,374			$928,109
1984-85	$ 32,000			$960,109

REPORTS

MACKAY G., HUFFMAN D., GRAHAM B., SADDLER J., KRYLA J., "Status of Biomass/Energy Conversion Technology - ENFOR Program Review," March 1982.

STATUS AND COMMENT

PROJECT DATA SHEET #	256	**PROGRAM IDENTIFICATION**	4.3.10 Bioenergy Project Management
TITLE	Bioenergy Program Management	**DURATION**	April 1981 - March 1984
CONTRACTOR	National Research Council Division of Energy R&D Montreal Road Ottawa, Ontario K1A 0R6	**COST**	$382,000
		SPONSOR	National Research Council
PRINCIPAL INVESTIGATOR	R.P. Overend Tel.: (613) 993-1342		

OBJECTIVE

To manage the incremental projects undertaken through the National Energy Program, specifically to provide technical assessment of the program, monitor progress and provide scientific guidance to research contractors.

DESCRIPTION

When new projects in Bioenergy Research were initiated in 1981 under the auspices of the National Energy Program it was recognized that an augmentation to the resources of the Bioenergy Program Office was necessary. Therefore 2 person-years and $100,000 in the first year were provided to facilitate effective program management of in-house research activities and contract research. This funding makes it possible for the Bioenergy Program Office to technically assess proposals and reports, and to evaluate technological advancements so as to fulfill the mandate of providing technical advice to the policy staff of Energy, Mines & Resources.

The expected outputs are:
1. Timely identification of technology advancement.
2. Immediate access to current status of all projects.
3. Timely achievement of technology transfer via appropriate media.

FUNDING

FISCAL YEAR	SPONSOR	CONTRACTOR		CUMULATIVE TOTAL
1981-82	$100,000			$100,000
1982-83	$132,000			$232,000
1983-84	$150,000			$382,000

CONTINUED

REPORTS

"Proceedings of the First Bioenergy Specialists' Meeting on Biotechnology (1984), ed. Moo-Young M. and Hasnain S., University of Waterloo Press (in press).

HASNAIN S. and OVEREND R.P., "Energy-Related Activities of the Canadian Biomass Research Program (1984)", Presented at the National Meeting on Biomass R&D for Energy Application, Arlington, Virginia (Proceedings in press).

"Proceedings of the Fifth Canadian Bioenergy R&D Seminar/Cinquième séminaire canadien R&D bionergtiques (1984), ed. HASNAIN S., Applied Science Publishers, London, NRCC 23490.

OVEREND R.P. and CHORNET E., "Hydrogen and the Upgrading of Biomass", in Hydrogen Energy Progress V., T.N. Veziroglu and J.B. Taylor editors., Vol. 4, pp 1773-1784, NRCC 23124.

OVEREND R.P., "Biomass Energy", in Physics and Contemporary Needs, Vol. 6, A.M. Khan, S. Riazuddin, Asghar Qadir and M.N. Qazi editors, pp 181-235, Plenum Publishing Corporation 1984, NRCC 19517.

"Comptes rendus de l'atelier de travail sur la liquéfaction de la biomasse", ed. Chornet E. and Overend R.P., September 1983, NRCC 23130.

HASNAIN S. "Overview of Federally Sponsored Biomass Combustion Research (1983)", presented at the Spring Technical Meeting of the Combustion Institute, Kingston, Ontario

Mechanization of Hybrid Poplar Plantations, Bioenergy Program, NRCC, 1983.

HASNAIN S. and DUMAS S.G., "Bioenergy Research and Development: A summary of the Federal Program from April 1982 to March 1983", NRCC 21207.

OVEREND R.P., "Biomass Conversion Technologies", in "Solar World Forum", Editors, D.O. Hass and J. Morton, V2, pp 1211-1220, Pergamon Press, 1982.

Proceedings of the Fourth Bioenergy R&D Seminar, Winnipeg, Manitoba, March 29-31, 1982, NRCC 20414.

"Specialists' Meeting on Biomass Liquefaction", ed. Eager R.L., Mathews J.F and J.M. Pepper Feb 16-17, 1982.

SUMMERS B.A. and HASNAIN S., "Bioenergy Research and Development: A Summary of the Federal Program from April 1981 to March 1982", NRCC 20068.

OVEREND R.P., "Wood Gasification Review of Recent Canadian Experience", In Energy from Forest Biomass proceedings of IUFRO Conference, Kyoto, 1981. Editor W. Ramsey Smith, pp 171-07, Academic Press, New York, London, NRCC 20094.

Proceedings of the Third Bioenergy R&D Seminar, Ottawa, Ontario, March 24-25, 1981, NRCC 19515.

"Biomass Liquefaction in Canada", ed. Boocock D.G.B., Mackay D. and Paterson S., August 12-13, 1980.

JUNÉJA S., NEALE R., OVEREND R.P., PNEVMATICOS S. and TIMBERS G.E., "Canada's Bioenergy Program", in Proceedings of Bioenergy '80 held in Atlanta, April 1980 by the Bioenergy Council, Washington, D.C., 1980, NRCC 18414.

SUMMERS B.A., "Bioenergy Research and Development: A summary of the Federal program to March 1980", NRCC 18454.

OVEREND R., "Bioenergy Potential in Canada", Technical Reports Division 3. Energy and the Environment. Volume 3 pp 245-265. 1980. Published by 11th

STATUS AND COMMENT

APPENDICES

APPENDIX I

ENERGY-RELATED ACTIVITIES OF THE CANADIAN BIOMASS RESEARCH PROGRAM

Sadiq Hasnain and Ralph P. Overend
National Research Council
Ottawa, Ontario, K1A 0R6

Abstract

The Canadian Government program on Biomass R&D is a reflection of a policy decision to increase Canadian energy independence by substituting a renewable resource for imported petroleum based fuels and feedstocks. The challenge was to mount an integrated and coordinated R&D program on problems as diverse as the genetic engineering of bacteria for the biological conversion of lignocellulosics, through environmental impact assessment to thermochemical liquefaction of wood, a diversity matched by the number of government departments and agencies which have related jurisdictional mandates.

Since the inception of the program notable progress has been made in the areas of resource assessment, setting of standards for combustion equipment, the gathering of data for the improvement of efficiencies and emissions from large industrial boilers, the development and commercial demonstration of a high rate anaerobic reactor, the development of fluidized bed gasification technology, a successful bench-scale flash pyrolysis process for wood liquefaction, a plantation tree harvester and many others.

At the present the major elements of the Canadian Program are undergoing considerable change. Most of the biomass inventory questions have been answered; a major techno- economic assessment of forest biomass conversion technologies has been completed and on the basis of these it is clear that the near term canadian biomass opportunities are with combustion applications in the forestry and related industries. There are however continuing R&D requirements in the area of emissions and regulatory aspects of combustion aswell as in forest residue recovery and new harvesting concepts.

A major portion of the bioenergy R&D effort has been towards the supply of liquid fuels. In thermochemical conversion, one concept - the pressurized O_2 fluidised bed reactor - is being taken to the demonstration stage while the prospects for direct liquefaction have been recognised as being longer term in the light of an IEA study.

In the area of the application of biotechnology for lignocellulosic conversion to liquid fuels, it has become apparent to us, and to other countries, that economics will continue to be a barrier for some time, particularly if the present forecasts for oil price hold true.

At the NRC, the biotechnology strategy for Bioenergy is seen as being heavily dependent on the development of multiple uses for the product streams produced from our major lignocellulosic resource base. Central to this concept are the fractionation concepts which are being extensively evaluated in our program along with downstream processes such as fermentation, separation and waste treatment.

Introduction

In Canada the majority of renewable energy outside of conventional hydroelectricity is derived from forest biomass. Climate and geography dictate that themajor biomass production is in the form of forests. Agricultural biomass production takes place on less than 7% of the land mass and is primarily towards a large export of wheat on the world markets. The zone of productive forest biomass in Canada is spread along its southern latitudes. Above the productive zones there is a gradation of marginal boreal forest, tundra and in the extreme north, ice and rock. Agricultural zones occupy a relatively small share of the total land mass. The area of highest forest productivity is found along the western coast ranging from a timber density of about 175 $m^3.ha^{-1}$ to over 420 $m^3.ha^{-1}$, or equivalent to a biomass mean annual increment of approximately 2 - 4 $ODt.ha^{-1}$. The major portion of the productive forest zone has a timber density of 70 - 175 $m^3.ha^{-1}$ equivalent to a mean annual increment of about 1 - 2 $ODt.ha^{-1}$ of standing biomass. These values are of course for natural forest stands which do not take into account the potential gain that could be realized through silviculture, intensive breeding programs and clonal forestry. An example of what could possibly be achieved in Canadian forestry is illustrated by the clonal plantations of hybrid poplar in Eastern Ontario. Yields of 7 - 10 $ODt.ha^{-1}$ have been reported, approximately five times the yield of natural forest poplars.

Intensive management would easily double the yield of Canadian forests(1) without improvements in the genetics of planting stock. However, a recent study by Forintek Canada(2) has shown that the fibre of fast-grown trees through intensive management is inferior to mature trees in a natural stand. But, since the quality of a tree is genetically determined (3, 4), it is clear that intensive manage ment must be integrated with intensive breeding for varieties which will make optimum use of the silvicultural inputs and at the same time possess other desirable characteristics of fibre quality, yield, disease resistance, etc. Clonal forestry through vegetative propagation (using cuttings, and in particular, tissue culture) is the only means for a rapid exploitation of the full genetic gain achieved in a breeding program (3, 4, 5, 6). With the state of forestry in Canada deteriorating rapidly, and projections of impending shortages of suitable fibre, at the right price, (7, 8) it is imperative that tree improvement and breeding programs be accelerated and their full potential of the genetic improvement be exploited through clonal forestry.

The relevance of forest productivity to bioenergy is a direct relationship. Nearly 80% of biomass used today in Canada is derived from conventional forestry operations. Increase in forest yield, therefore, will lead to yield increases both for forest products and biomass for energy. At present the forest industry is reluctant to accept increased fibre utilization even in the form of residues for energy purposes other than its own internal requirements. While, at a time of stable oil prices this may be justified, clearly in the long term with rising energy prices, there will be increased pressure to find alternatives to fossil fuels. Since it will make strong economic sense to integrate energy and forest products production, a doubled effort should be implemented for increasing forest productivity to avert potential shortages of low cost fibre for the industry and to assure an adequate supply of a cheap feedstock for fuels and chemicals. From a different angle, case studies have shown that integrated pulpwood and energy wood harvesting strategies are economic with the simultaneous benefit of accomplishing the first step in the silvicultural process of forest regeneration (ie., removal of diseased and low value material)(9).

Forest Biomass Availability and Price

Current estimates show that forest biomass represents 4.9% of the total primary energy demand. This is equivalent to 445 PJ. Of this total, 210 PJ are from pulping liquors, 135 PJ from wood residues and approximately 100 PJ are from combustion of roundwood for residential space heating, not including fireplaces.

Compared to 1976, the beginning of Federal Government programs to increase biomass utilization, biomass use has increased by 150 PJ, equivalent to an oil saving of 25 million barrels of oil equivalent per year (B.O.E./a). About a third of this increase can be directly related to federal incentive programs and federal/provincial demonstration programs. A conservative estimate suggests biomass will contribute 1 EJ of Canada's primary energy demand by the year 2000.

Figures 1 and 2 show the 1990 supply/price projections for biomass in Canada. It is now apparent that the share suggested for short rotation forestry (SRF) plantations will not be realized. This is due to the principal reasons of a drop and a stabilization in the price of fossil fuels and a serious down-turn in the economy leading to a slower pace of research and development (R&D) and demonstration than originally anticipated and, therefore, a slower rate of plantation establishment. Mill residues (Fig. 1), which represent some of the lowest price biomass available will make up about 15% of the forest biomass available. Most of this will be utilized for energy bv the forest industry directly, particularly since it is expected there will be a greater integration of lumber production with pulp and paper. Salvage, merchantable surplus and logging residues generate the bulk of available biomass with almost equal proportions of 25% each, while stand conversion for regeneration will contribute about 10%. The price for this biomass (Fig. 2) has a broad range from almost zero to above $100/t, moisture and ash free (maf). Most of the mill residues (about 12 Mt M= million) range in price from 0$ - 15$/t. Another 8 Mt consisting of mill residues and a mix of material from salvage, surplus, stand conversion, and logging residues range in price from 15$ - 30$/t. The bulk of material (almost 40 Mt) consisting of the above mix will cost between 30$ - 45$/t, while another 20 Mt will cost as much as 60$/t. The present demand for biomass from forest operations is about 16 Mt (maf), not counting domestic space heating. This suggests that even with a doubling of biomass utilization through combustion and gasification, almost 30 Mt would still be available for chemicals or liquid fuels production, for a theoretical yield of about 3 billion U.S. gallons of ethanol.

An interesting point to note is that since substantial amounts of material from salvage operations (fire and disease killed) and collection of logging residues and stand conversion can be extracted at a rather favourable cost, this should give added incentive and generate greater profitability in Canada for a more substantial forest regeneration effort.

APPENDIX I

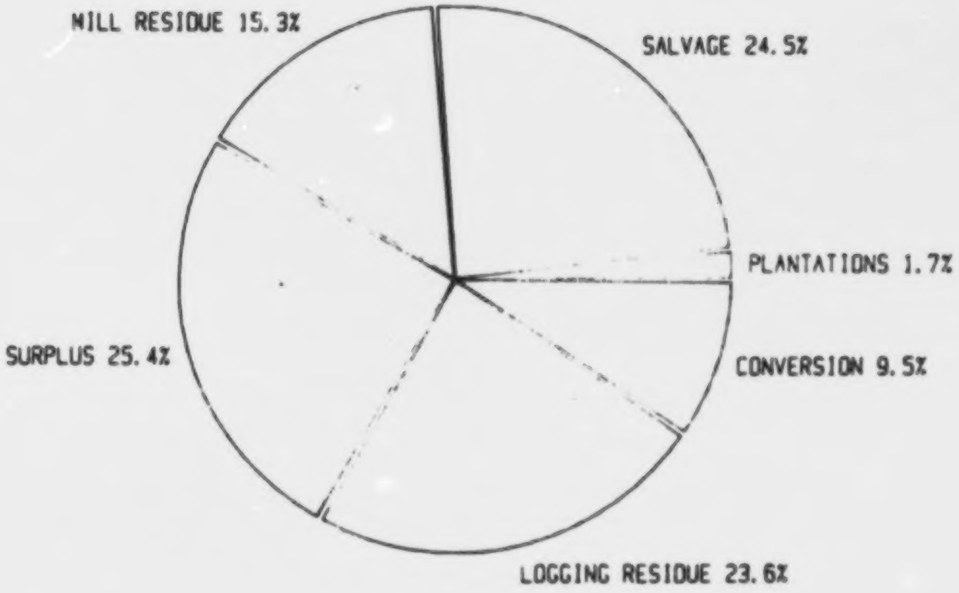


Figure 1. Forest Biomass Source and Distribution as a % of the total available in 1990 for energy and chemicals

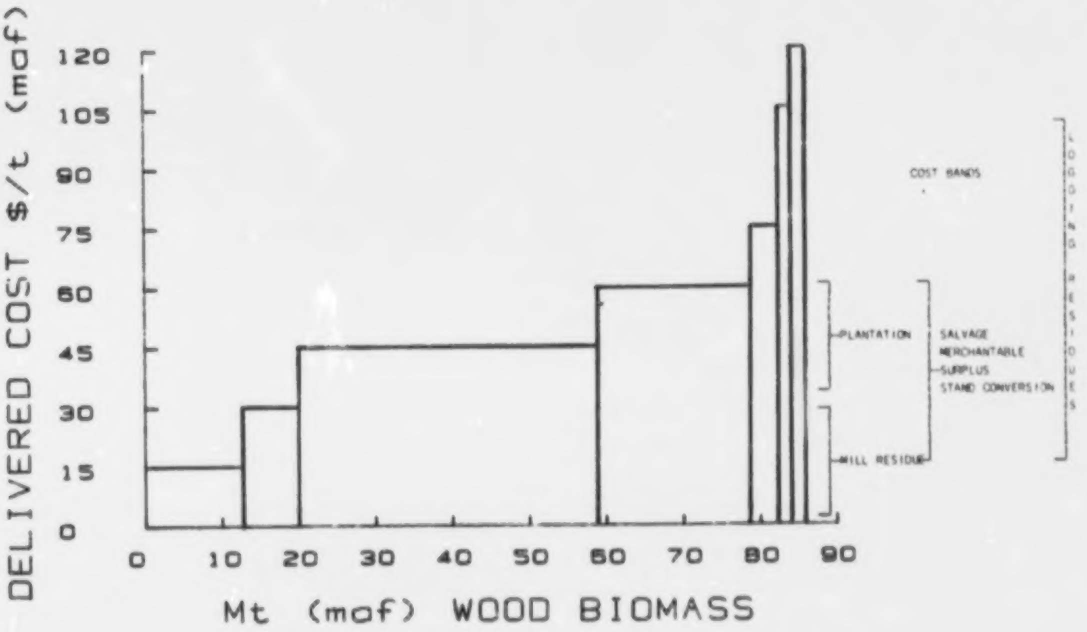


Figure 2. Supply/Price curve for forest biomass availability in 1990

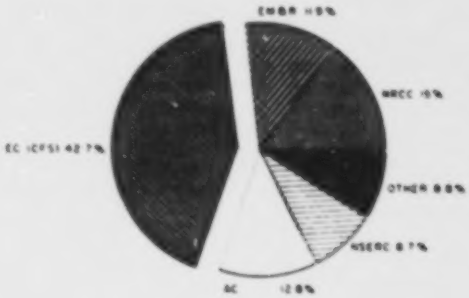
Agricultural Biomass

The existence of a major grain export industry based on the prairie, a region of low population density having relatively low cost energy available as natural gas has, resulted in only small utilization of grains for motor fuel in contrast to the U.S. Gasohol program. The research emphasis has in consequence been based on crop residues such as straw, chaff, stover and potato culls or on animal residues and manures, especially intensive husbandry of beef and pork. On straw availability, preliminary investigations by Agriculture Canada showed that, in the main cereal grain areas of the prairie provinces, soil tilth and moisture concerns demand the replacement of all the straw into the soil. This is neither practiced nor physically possible with conventional machinery, and thus some controversy continues. However, with possible increase in no-till methods in the future, a substantial quantity of straw could be available for local energy use, probably only for combustion purposes.

With Jerusalem artichokes, considerable work has been undertaken to hydrolyze the inulin and ferment the fructose. Near future predictions would suggest that liquid fuels from Jerusalem artichokes will not be economic but that it may be profitable to produce a high fructose syrup instead. In fact, due to the suitability of the crop to land used for growing tobacco, it is possible that farmers may grow it as a replacement crop due to a diminishing tobacco market.

History of Biomass R&D in Canada

There are a number of Federal Government departments and agencies involved in R&D funding for bioenergy (Fig. 3).



EC = Environment Canada
CFS = Canadian Forestry Service
AC = Agriculture Canada
NSERC = Natural Sciences & Engineering Research Council
NRCC = National Research Council Canada
EM&R = Energy Mines & Resources

Figure 3. % of Year Total Expenditures 1977-1983 (in dollars of the year)

Since the beginning of the Federal program, the Canadian Forestry Service of Environment Canada, through the ENFOR program, received the lion's share for contract R&D in silviculture, mechanization, pretreatment, materials handling and resource and environmental assessment and in the area of conversion including thermochemical and biological processes. Since April 1, 1984, the management of the conversion projects were handed over to the Department of Energy, Mines and Resources. EMR's primary function is setting energy policy for the country. They have some in-house projects in combustion of biomass but most of their biomass R&D activity is contracted out. Some of these projects are also the largest in terms of dollars because they are activities closer to demonstration and commercial application. One is the boiler test program which has turned out to be very successful, pointing out major inadequacies in boiler design from the point of view of efficiencies and emissions. In most cases only minor modifications have given considerable savings and improvements. The information being generated is fed back to the boiler manufacturers for improving design. This information transfer is facilitated by a direct involvement of the Canadian Boiler Manufacturers Association in the project. There are three other major projects managed by EMR. The

Iotech/ Monenco 1 t of wood/d plant using steam explosion, enzyme hydrolysis and fermentation to ethanol, will come on line early in 1985.

The gaseous HF solvolysis process, originally started by Canertech, is now being managed by EMR. Issues that still need to be addressed are reprocessing and recycling of HF and toxicity to the microbes. The lignin is unfortunately highly modified and is expected to be used as fuel. The other is the Biosyn project - a 21 MW 10t/h oxygen blown, fluidized bed gasifier for MJV gas. It is to be used for optimizing parameters such as moisture content of feedstock, operating pressure, oxygen, etc. It is expected that after cold tests this winter, full testing will begin in 1985.

The Natural Science and Engineering Research Council (NSERC) is a Federal Government granting agency for university R&D funding. They have identified, among other areas, biotechnology and energy of strategic importance. In these two categories there are a number of projects of interest to bioenergy development. Through NSERC, and a number of in-house projects at National Research Council, some badly needed basic research is ongoing. It is our feeling that all basic research is in real jeopardy in Canada for very much the same reason as the U.S. "Quadromania syndrome" in biomass R&D.

The National Research Council is the prime research agency of the Government. The NRC Bioenergy Program, managed by Ralph Overend, does not have its own laboratory facilities but funds projects in our other NRC laboratories such as Chemistry and Biological Sciences. The major R&D effort is, however, contracted out to universities, provincial research agencies, and to the private sector including institutions such as FERIC (Forest Engineering Research Institute of Canada) and Forintek. The R&D interests of the NRC Bioenergy Program span a wide spectrum from the use of tissue culture for producing superior trees all the way to downstream processing by reverse osmosis.

Agriculture Canada has parallel R&D interests to forest biomass on agricultural residues, energy crops and biogas. Overall, the mechanics of coordination among all of these various interest groups has worked reasonably well. Part of the reason has been that the funding has come from a special envelope which is distinct from the 'A' base funds of any department. This has allowed each department to be an equal partner in the relationship.

Figure 4 shows the total Bioenergy R&D expenditure trend, starting in 1977 with less than $1 million to about $14 million at the end of the 1983/84 fiscal year. It was three years after the beginning of the program that the second oil shock occurred. At this point, preliminary results of the ENFOR program justified the expansion of Bioenergy R&D in 1980, leading to an increase in the budget for conversion, energy crops and resource assessment and development.

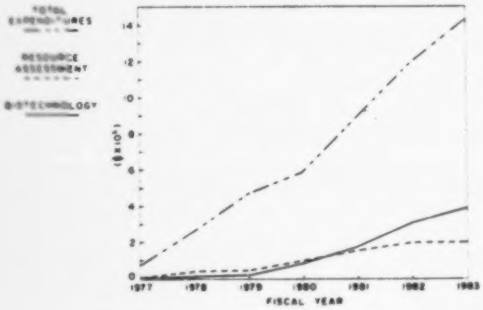


Figure 4. Bioenergy Program Development (Dollars of the year)

This expansion is also illustrated in Figure 5 which shows the diversification of the program in a comprehensive Bioenergy R&D effort with the greater involvement of other departments along with Environment Canada.

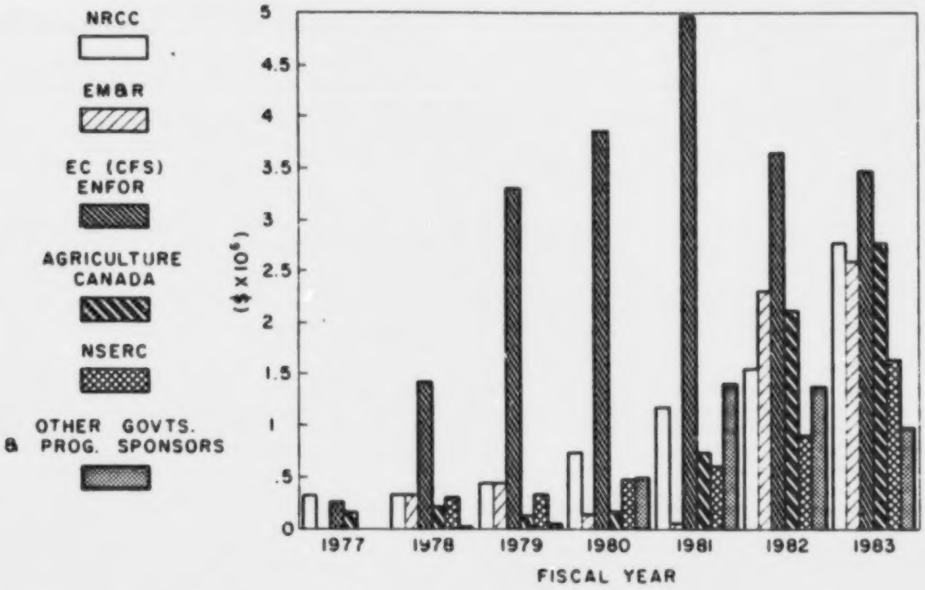


Figure 5. Program Evolution by Sponsor (In dollars of the year)

This diversification is further illustrated in Figure 6, which reflects the development of the major areas of bioenergy R&D over the last 7 years. In this analysis, the projects related to environmental assessment have been grouped under silviculture.

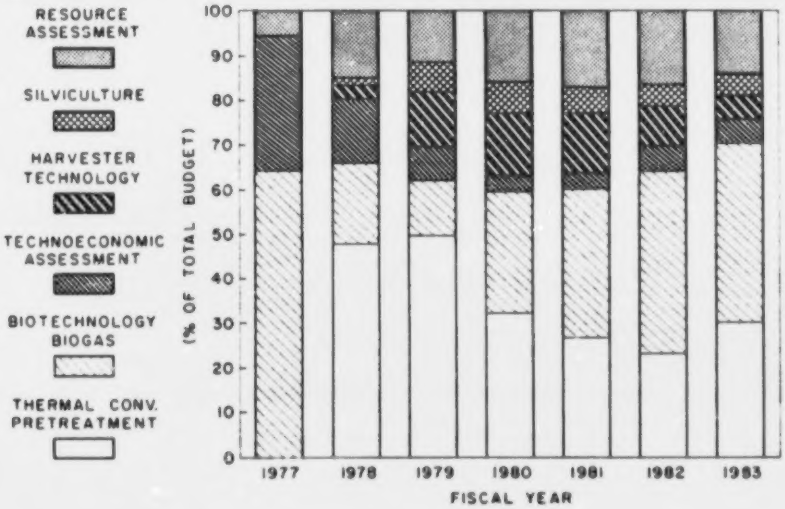


Figure 6. Program Evolution by Area

Resource Assessment

As shown in Figures 4 and 6, resource assessment has been a significant activity for locating the quantity of forest biomass from coast to coast. The work includes conversion of existing volume data on timber to actual mass data on the whole tree, the identification of biomass in relation to specific geographical location and by groupings of type and species. It will also be possible to determine how the quantity of biomass available for energy varies with harvesting methods and wood utilization and to determine the accessibility of the resource. This ENFOR activity, in cooperation with in-house work on new inventories of unsensored areas, is close to completion, and trials have already started in some regions of the country to determine the reliability of data. The last two years have seen an increased effort by Agriculture Canada. Much of this is associated with the assessment of residue availability and in the assessment of crops specifically suited for energy production both in conjunction with existing agriculture and the cultivation of under-utilized land. The purpose of this long-term program is to identify energy crops through planned cropping trials, observation of existing plant stands and development of agronomic practices.

Silviculture

Projects under this title could suitably be subtitled "forest management for biomass production in an environmentally sound manner". Two areas are achieving prominence: the growth of energy plantations, and the use of computer simulation to evaluate the consequence of different management and silvicultural practices. The former is the subject of considerable federal/provincial collaboration and participation in the IEA has resulted in significant attention being paid to this new area of silviculture. The computer model FORCYTE (FORest nutrient Cycling and Yield Trend Evaluator) developed under ENFOR is an ecologically- based forest management simulator designed to estimate the long-term consequences of intensified biomass production and harvesting. Several versions of the model have been developed, calibrated and tested and although originally designed and calibrated for Douglas fir ecotypes, the model is now being calibrated for, and applied to, other Canadian forest ecotypes through a series of ENFOR projects. The model has attracted considerable scientific interest world- wide, and is now being tested in several countries.

It is likely that in Bioenergy R&D, silviculture will maintain its relative share of both budget and priority as the program evolves.

Harvesting and Plantation Technology

Considerable effort has been concentrated in this area. Under ENFOR and NRC there have been several prototype systems constructed and evaluated in conjunction with FERIC (Forest Energy Research Institute of Canada) and the private sector. Highlights include:

- The RECUFOR for collecting and preprocessing logging residues which remain after short-wood harvests. A prototype was constructed and field tested; the concept and general design features are considered proven. Its large size and high cost may restrict its application.

- Logging Residue Processor (LRP; previously Recufor S). For collecting and processing (fully) logging residues accumulated along roads and at landings during full-tree harvests. Prototype was field-tested in summer 1984.

- Crabe Combine. This machine, a much modified Canadian version of the Finnish Palari Brush Harvester, is for swath harvesting and chipping brush and small trees. The high cost and very heavy carrier may limit the potential of this machine to special applications such as clearing rights-of-way.

- Separator Shear. For chunking large pieces and separating biomass and debris that accumulates in West Coast log sortyards. Prototype has been constructed and successfully tested.

Early field evaluations of existing methods of recovering forest biomass residuals in Newfoundland and New Brunswick have contributed directly to their utilization on a commercial basis. At the same time, the machinery development program has started to fill in some of the productivity shortcomings of existing machinery.

The development of plantation machinery is being pursued at NRC in conjunction with the Government of Ontario's hybrid poplar program in the Eastern Region. A complete system based on agricultural machinery is evolving to cover the cycle from field clearance, through planting and tending to final harvest. Three machines have already completed one year of successful field testing. One is a continuous harvester/buncher designed for 5-year hybrid poplar plantations. It is an attachment for existing agricultural tractors and has a productivity of 1000 trees per hour at a ground speed of 2.5 $km.h^{-1}$. The other two include a unique grapple skidder and a front-end loader for forwarding and loading the bunched trees.

Techno-economic Assessment

The major foundation of the ENFOR program was the InterGroup 1977 study which comprised nearly 30% of the program expenditures in that year. Since that time, techno- economic assessments have become a diminishing proportion of the budget. The current major techno-economic assessment is the ENFOR project C-258, QA Comparative Assessment of Forest Biomass Conversion to Energy Forms", which in 9 volumes, assesses the different unit processes in biomass conversion ranging from pretreatment, drying and chipping to alcohol production. The 6 data books are presently being released.

Thermal Conversion

Thermal Conversion, especially gasification and pyrolysis, were major elements of the early program since combustion was considered to be a "mature" technology. The program evolution has diminished the share of thermal conversion which has also become more involved with performance evaluations of large scale hog fuel boilers and of small residential heating units. In some respects the program elements have evolved in 3 different directions:

1. Technical service in support of FIRE (an incentive program to increase biomass utilization for energy by industry and institutions) and demonstration activities (mainly combustion and gasification)

2. Hand over of technology to the demonstration phase as with the Lamb Cargate Wet Cell/Lime Kiln at Port Alberni or, as in the case of gasification, a full scale demonstration under construction in Quebec referred to as BIOSYN

3. Return to fundamental studies as exemplified by the direct liquefaction work.

Pretreatment

This area of research covers the range from physical size reduction through to lignocellulosic fractionation prior to cellulose hydrolysis. In terms of technology development, it is presently a curious hybrid of commercial processes, such as the Bioshell process, demonstration activity as with the Iotech/Monenco 1 ton/day steam explosion process for a wood to ethanol plant, and Weston's Biohol extrusion process, and R&D as with the University of Sherbrooke thermomechanical procedure for lignocellulosic fractionation. It is becoming clear that increased effort in fractionation of lignocellulosics into lignin, cellulose and hemicellulose is justified in terms of potential value added to the separated fractions and this has been a recent growth area.

Biotechnology & Biogas

These two areas have shown consistent growth within the funding envelope for Bioenergy R&D. The scope of effort ranges from genetic engineering of yeasts to enable them to simultaneously saccharify cellulose and to utilize the sugars, to the operation and monitoring of 400 m^3 fixed film anaerobic digesters.

The story of anaerobic digestion in the Bioenergy R&D program is an example of the time scale that is required for development of a laboratory system to a commercially viable process. It is also a useful model for future bioenergy development since it illustrates the economic environment in which a Bioenergy process is likely to be viable.

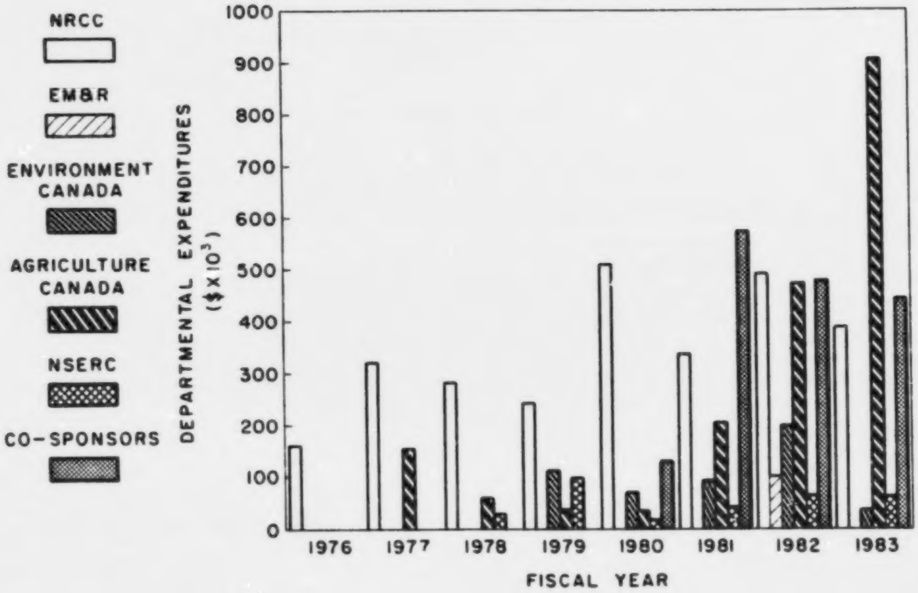


Figure 7. Biogas R&D Expenditures (In dollars of the year)

Figure 7 shows the pattern of program support since 1976. In the years prior to 1976, NRC had maintained a program looking at the treatment of food processing wastes. This served as the basis for the development of the Down Flow Stationary Fixed Film (DSFF) concept. Up to 1980, the majority of the work was in the laboratory though a number of early demonstration and pilot projects were undertaken by Agriculture Canada. The early demonstrations with the exception of the Roslyn Park Farm, were tehnical or economic failures (or both). The early "failures" of bulk anaerobic digesters brought into focus the developments called for in creating a viable technology. NRCC, Agriculture Canada and the private sector have worked together to bring the DSFF and other advanced concepts to full scale. From 1 successful operating STR (Roslyn Park) in 1980 there are now 11 advanced systems under construction or operation. These are working on animal manures as well as industrial wastes such as cheese whey.

Economically, the animal systems are successful if not only energy is taken but also there is protein recovery. The increased emphasis on energy/protein recovery and environmental improvement makes such advanced digesters economic at around 100 - 150 animals.

The NRCC DSFF technology has baen scaled up from 50 cm^3 working volume to 400 m^3, while a mobile trailer with a 1 m^3 unit is being used to test out the different industrial wastes in eastern Canada. The current phase of demonstration units are likely to be evaluated before major new demonstrations are undertaken. The funding by sponsors in the Biogas program is also a measure of the maturing of a technology as it is transferred away from the laboratory to the private sector.

During the scale-up and demonstration of the DSFF reactor concept, laboratory work at NRC has continued on developing the next generation of advanced systems. A hybrid sludge blanket and filter bed reactor has given the highest rates of methane production achieved to date at NRC, equivalent to 10 m^3 of methane per m of reactor volume per day, a substantial improvement over the 1 $m^3/m^3/d$ that was common in the early 70's.

The Future

The major Canadian biomass resource is the lignocellulosic resource, forest biomass, while agricultural plant stalk materials such as straw and stover make up the rest. The growth of the bioenergy program during the 76-84 era has been parallelled by the upswing of interest in Biotechnology. The bioenergy R&D program has in a sense provided the front end of what could ultimately be the basis of a "new" resource based industry providing Fuel, Fibre, Food and Chemicals. The resource assessment has established a raw material base in excess of 50 Mt/a of forest biomass available at a cost of $45/t delivered to a processing plant. A wide range of options are available for this wood biomass. Clearly, in site specific circumstances saccharification using dilute acids or liquefaction and pyrolysis could be economic. Such circumstances will almost certainly only occur where extremely low cost process residues are available. The required value added to justify large scale use of a 45$/t resource will have to come from fractionations such as organosolv and aqueous steam extraction followed by value maximisation of the cellulose, hemicellulose, and lignin streams.

The new biotechnologies will play their role through a process which will optimally utilize each of these streams. Biotechnology is also likely to play a role in rapidly developing new varieties of biomass species engineered or bred for specific qualities or even chemical composition. Today's forestry and agriculture is optimized for the production of long fibres for pulp, specific strength and density characteristics for solid products and foodstuffs, new conversion processes could call for more biomass production per unit area and for modified properties such as in the ratios of hemicellulose to cellulose and lignins as well as their composition. The early work in cloning and macropropagation of Populus and Salix is an encouraging example of the significant productivity gains that could be achieved not only for hardwoods but also for the softwoods with the application of concerted breeding programs. For the future, the potential is even far greater if we can bring to bear the full array of plant tissue culture biotechnology on biomass productivity.

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APPENDIX II

CLASSIFICATION INDEX

SUB-PROGRAM 4.3.1 BIOMASS RESOURCE ASSESSMENT

4.3.1.1 - Forestry - Mill Wastes

4.3.1.2 - Forestry - Logging Residue

4.3.1.3 - Forestry - Biomass Factors

4.3.1.4 - Forestry - Energy Plantations - Productivity

4.3.1.5 - Agriculture - Animal Residues

4.3.1.6 - Agriculture - Plant Residues

4.3.1.7 - Agriculture - Energy Crops

4.3.1.8 - Peat (not included in program after March 1981)

4.3.1.9 - Algae

SUB-PROGRAM 4.3.2 ENVIRONMENTAL EFFECTS

4.3.2.1 - Forestry - Silvicultural and Harvest Impacts

4.3.2.2 - Forestry - Conversion Technology Impacts

4.3.2.3 - Agricultural - Agricultural and Harvesting Impacts

4.3.2.4 - Agricultural - Conversion Technology Impacts

4.3.2.5 - Peat - Harvesting (not included in program after March 1981)

4.3.2.6 - Peat - Conversion Technology (not included in program after March 1981)

SUB-PROGRAM 4.3.3 INTERNATIONAL PARTICIPATION

4.3.3.1 - International Energy Agency "Short Rotation Forestry for Energy"

4.3.3.2 - International Energy Agency "Biomass Technical Information Service"

SUB-PROGRAM 4.3.4 SILVICULTURE

SUB-PROGRAM 4.3.5 BIOMASS PLANTING, HARVESTING AND COLLECTION TECHNOLOGIES

SUB-PROGRAM 4.3.6 BIOMASS CONVERSION TECHNOLOGIES

4.3.6.1 - Biogas Production

4.3.6.2 - Fermentation to Alcohol

4.3.6.3 - Low Joule Gasification

4.3.6.4 - Medium Joule Gasification

4.3.6.5 - Methanol

4.3.6.6 - Direct Combustion

4.3.6.7 - Char Production

4.3.6.8 - Oil Production - Liquefaction

4.3.6.9 - Chemical Feedstocks e.g. NH (but not including transportation fuels)

4.3.6.10 - Electrical Generation

4.3.6.11 - Pyrolysis

SUB-PROGRAM 4.3.7 BIOENERGY - STRATEGIC STUDIES

4.3.7.1 - Anaerobic Fermentation

4.3.7.2 - Fermentation of Pentoses

4.3.7.3 - Genetic Manipulation of Microbial Strains for Energy Production

4.3.7.4 - Fluidizable Heat Storage

4.3.7.5 - Molecular Models of Photosynthesis

4.3.7.6 - Solar Energy Conversion via Photosynthetic Bacteria

4.3.7.7 - Catalytic Synthesis

4.3.7.8 - Membrane Applications in Gas & Liquid Separations

4.3.7.9 - Biochemical Production of Hydrogen

4.3.7.10 - Oil-Bearing Microbes

4.3.7.11 - Immobilized Cell Techniques for Fuel Production

4.3.7.12 - Cellulase

SUB-PROGRAM 4.3.8 SOCIO-ECONOMIC-TECHNICAL STUDIES

4.3.8.1 - Social Infrastructure

4.3.8.2 - Technology Assessment

4.3.8.3 - Economic Assessment

4.3.8.4 - Information

4.3.8.5 - Legal Studies

SUB-PROGRAM 4.3.9 BIOMASS MATERIALS HANDLING, TRANSPORTATION & PRE-TREATMENT

4.3.9.1 - General

4.3.9.2 - Materials Handling

4.3.9.3 - Transportation

4.3.9.4 - Pre-treatment

SUB-PROGRAM 4.3.10 BIOENERGY PROJECT MANAGEMENT

REPORT AVAILABILITY

The reports listed in the project summary section of this publication may be obtained from the organization listed below. A complete listing of all Bioenergy research and development reports available is given in Appendix IV.

The Energy Library a part of the National Science Library known as the Canada Institute for Scientific and Technical Information (CISTI), is the official repository of all scientific reports produced by or on behalf of the government of Canada. Therefore, two copies of each report of the bioenergy program are supplied to the Energy Library from which they are available through interlibrary loans. For information contact:

Energy Library
Canada Institute for Scientific and
Technical Information (CISTI)
National Research Council
Room 29, M-55
Montreal Road
Ottawa, Ontario
K1A 0S2

Phone (613) 993-3861
Telex NRC LIB OTT 053-3115

The ENFOR Secretariat has a limited supply of reports on projects sponsored by Department of the Environment. These reports are available free on request. For information contact:

ENFOR Secretariat
Canadian Forestry Service
Department of Environment
19th Floor
Vincent Massey Building
351 St. Joseph Blvd.
Hull, Québec
K1A 1G5

Phone (613) 997-3409

Agriculture Canada reports in print or on microfiche are available from the **Energy Library of CISTI**. The microfiche reports are distributed for a charge of $2.20/microfiche.

NRC Publications Office supplies priced publications of the bioenergy program. Requests, accompanied by cheque or money order payable to Receiver General of Canada - Credit National Research Council, should be sent to:

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National Research Council
R-88, Montreal Road
Ottawa, Ontario
K1A 0R6

Phone (613) 993-2054 or 993-1996

APPENDIX IV

BIOENERGY R&D REPORTS

Reports are available on loan from the Energy Branch Library Canada Institute for Scientific and Technical Information, National Research Council, Montreal Road, Ottawa, Ontario. K1A OR6. Reports prefaced with an asterisk are available at nominal cost from NRC Publications, M-58, Montreal Road, Ottawa, Ontario. K1A OR6.

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APPENDIX IV

BIOENERGY R&D REPORTS

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APPENDIX IV

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